Chapters on Papermaking

VOL. V.

CONCERNING THE THEORY AND PRACTICE
OF BEATING

BY

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WITH PHOTOMICROGRAPHS AND OTHER ILLUSTRATIONS

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PREFACE.

THE work which forms the subject of this volume was undertaken for a series of articles which appeared in THE PAPER MAKER. The actual tests from which the author has drawn his conclusions were undertaken by different papermakers, whose generous assistance is acknowledged in the text.

The preliminary remarks referring to the Hollander and its mode of action formed the subject of one of the Croxley Lectures, delivered on behalf of the Hertfordshire County Council, at the suggestion of Sir John Evans. Those recorded in Chapters III. and IV. are the copyright of Messrs. Masson, Scott & Co., Ltd., to whom the author is indebted for permission to make use of same in this volume. Although many of the trials herein recorded were made by papermakers and engineers for purposes of their own, the greater portion were undertaken at the author's suggestion on lines which he had suggested in communications to trade journals. It must be self-evident to those who have made a study of Beating that the results dealt with are a few only of the many beaters and materials to be beaten. The book, incomplete as it is, contains all those trials that have come under the author's notice that admit of anything approaching systematic treatment.

There is practically no literature available, either here or abroad, on the lines of this work, and it is to be hoped that more will be forthcoming to the author as the result of the publication of these results in book form.

The subject of Beating has been too little studied from a scientific point of view to admit of methodical treatment in a text-book, consequently the work is here recorded very much in the order in which the results came to the author's notice.

In a short appendix is given an abstract of some correspondence which makes clear the common origin of the words "Potcher" and "Poacher." It is gratifying that the question of their origin should have been raised by the eminent lexicographer, Sir James Murray, and that he should regard these inquiries with a view of establishing their origin as resulting in a satisfactory explanation.

The author would like finally to express his indebtedness to his colleague, Dr. H. P. Stevens, for his general assistance, more particularly in connection with the chapter dealing with the measurement of fibres during beating, the figures for which have been largely drawn from joint researches.

Laboratories: 15, The Boro',
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INTRODUCTORY CHAPTER.

Early beating appliances—The Hollander—Its construction and mode of action.

UNDER the general term of Beating may be included those mechanical operations resulting in the mechanical reduction or subdivision of the fibrous raw materials used in the manufacture of paper, from the state in which the papermaker finds it after the boiling and bleaching operations to that of "finished stuff," as ready for the paper machine.

The process of beating forms the connecting link between the preparatory and chemical processes, and the making of the web or sheet, and is therefore the very centre of papermaking. A great deal depends upon the beating operation. The sheet may be said to be made or marred in the beater house, and no amount of care or skill on the part of the machineman will rectify carelessness or want of skill on the part of the beaterman.

There are a hundred and one complexities that may arise in the beater house, and as many effects to be produced by some variations in the mode of procedure, but the main process is all along the same, namely, the mechanical reduction and subdivision of the material.

It goes without saying that the *amount* as well as the *kind* of reduction must vary with every class of raw material to be operated upon. The same may be said of any one class of material when the same is made to do service for different kinds and qualities of paper, as well as for any one kind or quality of paper when produced in different weights and substances.

A large range of effects can be produced by means of a simple instrument like the papermaker's beater or Hollander with any one class of material that it is capable of operating upon.

The general principles of beating can perhaps best be grasped, *at any rate* as a preliminary study, by confining one's attention to

the ordinary Hollander. We will, therefore, take the Hollander, or ordinary beater, as a type, as by so doing we shall have a much better chance of grasping the general principles of beating than if we make an attempt to compare the different types of beaters now in use. Each papermaker has a good deal of knowledge of the particular beaters he has worked, but there is no information available at present in regard to the working details of all the various beaters in use, and therefore it is difficult to make a comparison between them.

There is a possible rough distinction between "beating" and "breaking-in." The process of breaking-in is the reverse of that of weaving. The weaver takes the spun yarn and weaves it into a fabric. In breaking-in, the fabric is converted back into a floating, wet, more or less mutilated mass of spun yarn. The breaker simply draws the rags to pieces without unspinning its threads. It does not reduce the fibres to their ultimate condition, it only unravels the weaving. By the separation of the individual fibres one from the other, the beaterman during the first process of beating undoes the work of the spinner. Having unravelled the ultimate fibres, the beaterman proceeds to cut these to smaller particles, the length and condition of which will depend upon the strength, texture, substance, and other qualities of the paper to be produced.

Fig. 1.

The subject of "Beaters and Beating" might well occupy the space of a large text-book; if we could accumulate and compare the knowledge possessed in different mills on this important subject, some valuable deductions could be arrived at. But for various and obvious reasons this information as a whole is not yet obtainable.

The very earliest attempts to reduce pulp appears to have been by certain savage races, who chewed up vegetable products until reduced to a more or less pulpy condition, and, when sufficiently masticated, the pulp was spat out on a porous surface to dry. Probably the saliva, if the mass is allowed to remain in a moist condition, assisted materially in dissolving the incrusting matter.

An advance on this primitive method of reducing vegetable fibre to pulp is the hand-pestle and mortar. Fig. 1 shows a form as up till recently used by semi-barbarous races.

Prior to the introduction of the Hollander, and at the time the "retting" or rotting process was in vogue, the disintegration was effected somewhat on the lines on which gold ore is crushed by means of stampers. Dr. Arnot described this in his lecture before *the Society of* Arts, in 1877, as follows:—"The implements

employed may be regarded as a species of mortar with a tight fitting pestle or stamper. The motars were constructed of stone or wood, and the stampers were moved by levers actuated by projections fixed on the water-wheel shaft. The charge of rags for one of these mortars was about 3 lbs., and it took about 24 hours to complete the operation. Under this process there was no cutting or tearing, consequently the fibres were long, and paper so produced was of great strength. To keep one of our largest paper machines at work no fewer than 5000 mortars would be required." These mortars were slow in their action, and did not cut the fibres. The stuff produced was consequently very long and worked "wet." One would expect that after beating for 24 hours, the stuff would work "wet." If, during the retting process, the cellulose was not injured, the paper produced by the

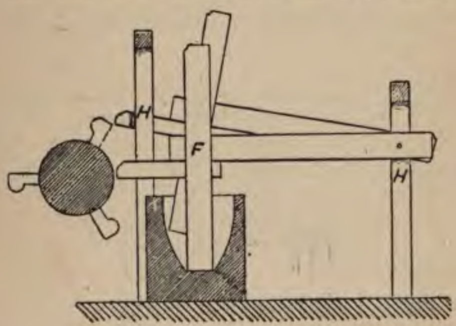


FIG. 2.

aid of these mortars was of good strength and durability. It is probably due, in a measure, to this cause that so much of our ancient literature has been so well preserved.

Fig. 2 is a side elevation of a battery of stampers, such as were in vogue up to the time the Hollander was introduced. The mortar is here oblong in shape, being gouged out of the trunk of a tree, and furnished with several stampers which rise in succession, as shown in the figure. The stamper was made to stand exactly horizontally when it strikes the bottom. The whole was made of wood, but the bottom of the mortar and stamper were shod with iron or furnished with iron nails.

Fig. 3 shows a view from above of the wooden Hollander as used in Germany about 1735.

Hofmann appears to credit Germany with the introduction of

the Hollander. He claims that the Germans were the originators of the Hollander, that it was copied by the Dutch, and that the Germans reintroduced it at a later date with the addition of using wind-mills to drive them. This statement does not appear to have been made by any other authority, and the writer does not consider it to be justifiable. It would be fairer to take an earlier authority, such as Koops, who, in the year 1800, speaking of the mills on the continent, says, "In Gelderland are a great many,

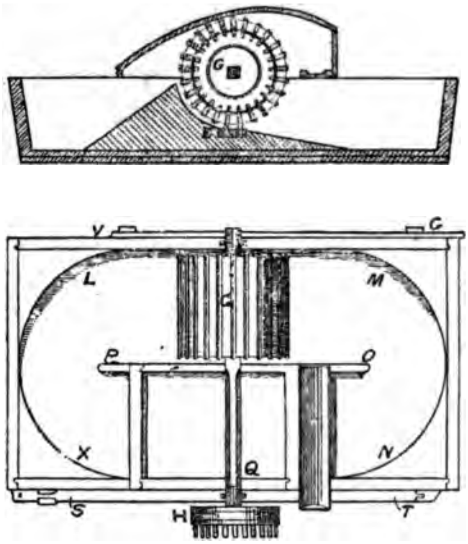


Fig. 3.

but some so small that they are only able to make 400 reams of paper annually, and there are also water-mills like those in Germany. But in the provinces of Holland there are windmills with cutting and grinding engines which do more in two hours than the others in twelve." This undoubtedly refers to the Hollander. In the report of the Jurors of the Exhibition of 1851 is found a good deal of information on many industrial subjects, among which is information on the early history of papermaking. In this report is the following statement :—"Cylinders with sharp *steel blades for tearing* the rags were invented in Holland." We

may conclude then that Hofmann is wrong when he states that the Hollander was the invention of Germany.

The above quotations are given in order that the Dutchman may have his due as the inventor of the Hollander. The claim of the Dutchman to the invention of the Hollander has, however, not been questioned in this country.

Happily, there still exist in this country a few millwrights who can build a complete wooden Hollander out and out, including forging the steel bars with which it has to be provided. Such Hollanders, when carefully made, will, in the writer's opinion, produce as good stuff as any of the more modern type.

The Hollander may be roughly described as an oblong trough with semicircular ends; the mid-feather, or central portion, running from the imaginary centre of one circle to the other. If one takes the dimensions of the Hollander, it will be found that the width is just about one half the length. No matter whether it is a small engine or a moderately large one, the depth does not vary so much, *i.e.* 1 foot 10 inches to 2 feet deep at the shallow end, with another 5 inches of depth at the "back fall" end. The size of the roll is, roughly speaking, in comparison with the size of the engine. The shaft of the beater roll should be just high enough so as not to obstruct the flow of the stuff. The bed-plate has to be situated at a convenient distance, so that when the roll is down, the shaft is just clear of the flow of the stuff. The diameter of the beater-roll will vary anywhere from 3 feet to 4 feet 6 inches. The width of the roll will vary anywhere from 2 feet 6 inches to 4 feet 6 inches. There must be no sharp corners or edges in a beater. The sides, as well as the mid-feather, slope off so as to form a rounded bottom; of course, this is absolutely essential in order to prevent any lodgment of the stuff. The roll, of course, should be as wide as it possibly can be, so as to very nearly fill the space between the mid-feather and the side of the engine, leaving only about $\frac{1}{2}$ inch daylight. In order to prevent any stuff from lodging between the ends of the roll and the walls of the beater, head-strips of metal are often screwed on, which in their revolution drive any stuff forward. These strips of metal are fastened in such a way as to prevent any lodgment on the sides of the beater; if they are placed in a sloping position or in a curving position instead of radially as the spokes of a wheel, they more effectually throw the stuff forward. There seems to be a difference of opinion as to how much space should be allowed between the ends of roll and walls of beater. Some papermakers think there should be *a considerable space*, something like $1\frac{1}{2}$ inches, and that these

pieces of metal perform some special function and help to drive the stuff forward. The author does not, however, think that this is the prevailing opinion ; moreover, making the roll narrow would reduce the beating power of the engine considerably.

Fig. 6 gives a bird's-eye view of the Hollander as ordinarily constructed. The arrows indicate the direction of the travel of the stuff. Fig. 5 shows the same in longitudinal, and Fig. 4 in cross-section. By the aid of these figures the explanations given in this chapter can better be understood by those readers not already acquainted with the construction of the Hollander. These drawings are specially prepared for the purpose by Messrs. James Milne & Son, of Edinburgh.

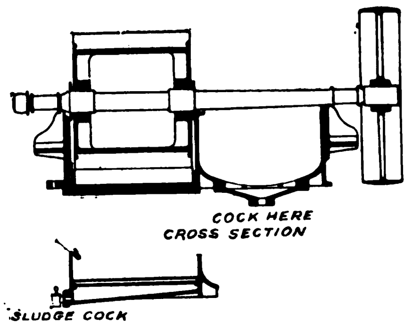


FIG. 4.—Cross-section of breaking engine.

The shape of the backfall (Fig. 5) is of the utmost importance. On the opposite side of the mid-feather to where the roll is situated, the centre of the bed of the beater is all on one level. But the bottom, on the side on which the roll is situated, shelves upwards from the end of the mid-feather in a regular incline to where the bed-plate is situated. (In the old beaters, at any rate, that was so, but there has been considerable modification in the shape to suit local requirements.) Then it curves upwards, taking somewhat the same curvature as the roll, until it reaches a level not much below that of the edge of the beater or the centre of the spindle, and from this point it curves downwards again on a steep incline. Of course the bed-plate is situated directly under the centre of the roll. Close in front of this is a perforated plate over a hollow channel running across the bottom. Another and larger sand-trap may be situated on the centre of the trough opposite to where the roll is situated, as shown in Fig. 6. Through these perforations any particles of sand, buttons, hooks and eyes, etc., find their way, and can be removed from time to time by opening a valve. The rolls of the Hollander of modern type are raised and lowered at each end of the spindle simultaneously. The earlier beater-rolls, some of which are still in use, are raised from *one bearing only*, *i.e.* the bearing close to where the driving pulley

is fixed. This was necessary when the beaters were driven by means of cogs. The disadvantage of driving by raising one bearing only is very obvious—the roll does not come down parallel on

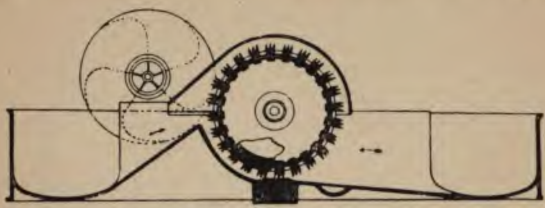


FIG. 5.

the bed-plate, it comes down at an incline, and it has a tendency to wear away the bars of the bed-plate more on the side on which the movable bearing is. Hofmann fails, I think, to give a correct

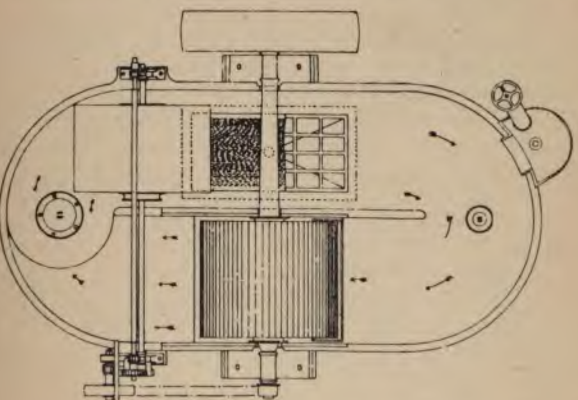


FIG. 6.—Combined breaking and beating engine, with drum washer, false bottom, button catcher, and breast washer.

explanation of this wearing away on the outside. It cannot, in my opinion, be due to the travel of the stuff, as there is a greater travel of stuff on the inside than on the outside, which should tend *to have the opposite* effect, namely, to wear the ends of bars near

the mid-feather more rapidly than the outside ends. The correct explanation is, I think, that when the bars are first set in the beater-roll and bed-plate, they are made to touch from end to end when they just brush one another. When the roll is further lowered (as when the bars wear away) the bars of roll must of necessity be inclined from the fixed bearing downwards, in consequence of the axle of the roll leaving the horizontal line on further lowering. This must of necessity cause more wear on the outside end of bars of bed-plate. This was, in part, remedied in some mills by slightly lowering the so-called fixed bearing from time to time, but with cogwheel driving this can only be done within certain limits without impairing the driving efficiency of the cogs.

The early beater-rolls were made of wood (Fig. 3). This relieved the beaterman of a great deal of responsibility, as the rolls, being light, could be let down with their whole weight on the bed-plate without injury to the rags. The beaterman did not lower the roll by degrees, he let it down rather quickly. If a lot of rags got between the bed-plate and the roll, the latter would jump a bit and allow the rags to pass without too much mutilation. It was not possible to hasten the beating with wooden rolls as it is with the more modern iron ones. The stuff had to take its time in the beater—there was no means of accelerating it. Such slow beating, although it was safe and sure, would not suit modern requirements. The stuff was drawn out and not cut, and in consequence of its being so long in the beater it had a great tendency to work "wet." There was not the risk of spoiling the stuff as there is with the more modern beaters. It is important for beatermen to realize that, with more modern and powerful appliances, greater skill and care are required on their part, as more now depends upon the way the beater is handled than formerly. The iron beater-rolls are made hollow in order not to make them too heavy. The spindle is generally made of wrought iron or steel, and tapers from the inside of the beater-roll to the bearing against the driving pulley.

Formerly beaters were driven by cogwheels fitted with wooden cogs, now they are almost universally driven by straps. By the old method of having one fixed bearing, driving by cogs was practicable. In order that one cogwheel may drive another properly, they should remain at a given distance apart. This, of course, could not be done if the bearing next the cogwheel moved up and down. When the beater is driven, as it nearly always is, *from below, there* is no necessity for top bearings as there would

be with those which are driven from overhead, where the pull of the strap has a tendency to raise the roll off the bed-plate, or the spindle from its bearing. A good method of lubricating the bearing, and one so long in vogue until properly designed lubricants came into general use, is to place a piece of raw mutton fat on the exposed half of the spindle above the brass. The fat becomes cooked through the heat generated by the friction, and by this means provides a constant supply of oil.

The action of the beater-roll is twofold. Its chief function is to disintegrate the fibrous material by the fly-bars coming in contact with the bars of the bed-plate. Its second function is to promote the circulation of the pulp. The circulation is promoted by the bars projecting from the roll, which cause a twofold action. It is best to examine the sectional elevation of the back-fall (Fig. 5) to see how this is effected. Firstly, in the way the bucket-lifter acts for conveying stuff to the machine, or as the paddle of a steamboat. To bring about this bucket-lifting action, it is necessary that the back-fall should follow the curvature of the roll, and be as near the fly-bars as possible, so as to give the best effect of lifting the stuff, and so prevent it from sliding back. The second mode of action of the fly-bars is due to centrifugal force. This force tends, when the roll is rapidly rotating, to cause the stuff to fly off in a straight line at what is known as a tangent. A tangent drawn to the point at which the fly-bars leave the last bar on the bed-plate determines where the centifugal force would naturally project the stuff. To get the greatest benefit from this, the back-fall should not be too near the roll sides ; very close proximity has a tendency to get in the way of the stuff flying off. It will be noticed that the back-fall is so constructed that it will take advantage, as far as possible, of these two somewhat opposing modes of action.

FIG. 7.—Beating engine.

As to the arrangement of the bars in the bed-plate, it will be noticed that they are placed close to one another and equidistant. The number may vary from 2 to 20. The distances apart vary considerably according to requirements. Their surface has to take the curvature to the roll itself. These bars are never placed in a straight line with the fly-bars. It is important to appreciate the influence of placing the bed-plate bars at an angle with the fly-bars. If the angle is very slight, we have a great

amount of tearing action. Supposing that a beater were constructed with the bed-plate bars parallel with the bars on the roll, here we have the greatest amount of tearing or unravelling action, and practically no cutting action, and one in which the beater requires the greatest amount of power as far as more force is required to rend the fibres asunder than to cut them.

To realize this, call to mind a pair of shears cutting a sheet of brass. When the shears are open at an angle of 45°, it is easy to cut the metal through, but in proportion as the shears close the force required becomes greater in consequence of the cutting action becoming less as the angle becomes less. A steel punch which punches a hole in thick metal may be instanced as an example of a machine which does not cut at all, but rends the surfaces asunder. The edges of punch and bed below meet one

FIG. 8.—Large breaking engine, built of cast-iron plates.

another somewhat in the same manner as fly-bars and bed-plate bars do when not placed at an angle.

The early bed-plates are straight bars inclined at a slight angle to the fly-bars, so as to give a slight cutting action. Many of the later ones consist of elbow-plates. They slope in one direction only to the middle, and slope back again. Now, what effect would that have on the beating? It has two effects. First of all, there is the best cutting effect; and secondly, the admixture of the stuff is promoted by the flow from the sides to the middle. The flowing stuff, being brought in contact with the elbow bars, is naturally drawn towards the middle by the slope of the bars. In some beaters it is possible to tell when the beater has elbow plates from the surface of the stuff as it leaves the beater roll, as in such cases the stuff is piled up in the centre. Angle-plates of all kinds have an injurious effect on the fly-bars of the beater roll. Where the point of the angle touches the fly-bars, the latter wears away

more rapidly, forming indentations in the bars, and necessitating their more frequent sharpening.

Plates, the bars of which are zigzagging several times in their length, their angles being 90°, and making an angle of 45° with the bars of the beater roll, would presumably possess the greatest cutting power. The chief function of the beater is not so much to cut as to draw asunder, at least for ordinary qualities of paper. It is only for papers such as blottings that the process in the beater becomes essentially a cutting operation. In such cases the bars are kept sharp, and the beating is conducted as quickly as possible.

Some elbow-plates are made with a long arm and a short arm. The long arm, of course, makes a more obtuse angle with the bars of the beater roll than the short arm, consequently the cutting effect is greater on one side of the roll than on the other, and if it were not for the fact that the angle plates tend to cause the stuff to flow together and intermix, the stuff would, on the one side, be more cut and less bruised and drawn out than on the other side.

By the aid of a plan of a Hollander it can be demonstrated, by a very simple calculation, that the stuff in contact with the mid-feather has only about half the distance to travel to make one complete revolution of the beater, in comparison with the stuff on the outside. As the roll tends to throw off an equal stream of stuff across this width, we would naturally infer that the stuff coming in contact with the mid-feather would pass round the beater in half the time that the stuff takes in contact with the outside of the beater. On the assumption that the stuff received a greater amount of cutting action on the outside than on the inside, by means of the last mentioned form of elbow plate, this in a measure tends to equalize the beating, as the stuff which travels slowest is submitted to the greatest amount of cutting action.

Although by such means the two sides of the stream of pulp issuing from the beater roll may be submitted to the same degree of diminution, the effect is different in kind in the two cases, and if it were not for the intermingling of the pulp from one side to the other the pulp would be wanting in uniformity.

Perhaps the greatest effect in cutting power would be to have bed-plates with zigzag bars forming an angle of 45° with the fly-bars. These plates tend very much to wear the fly-bars away just at the points of the angles.

It has been argued, with some degree of justification, that only the first bar or two on the bed plate of the Hollander is *effective in the beating*, the others being there mainly to give

support to the beater-roll, and that it is possible to beat as rapidly with one bar as with a number. The rate of wearing away would of course be much greater on the one bar than on, say, 20. The one bar would have, moreover, to be of a curious shape to engage with the surface of the beater-bars, and there would be the danger of the beater-bars interlocking with the single bar, nevertheless it is claimed, and I believe with a certain amount of justification, that the front bar of the bed-plate does most of the work.

The adjustment of the beater-roll to the bed-plate is a most delicate operation, and for such a purpose the mechanical means of adjustment would appear to the uninitiated to be a very crude

FIG. 9.—Improved breaking and bleaching engine with two rolls and two drum washers.

operation. The means of mechanical adjustment has been, however, considerably improved during recent years. The idea of automatically lowering the beater-roll has been ventilated, but has never found favour among practical men. The exact position of the roll can, in the author's opinion, be determined better by the "feel" than by any means of mechanical adjustment. The beaterman with practice can get to judge this, we might have said, "to a hair's breadth"; but, as a matter of fact, the means of adjustment can be regulated by the beaterman to a greater degree of nicety than the breadth of a hair. An automatic adjustment has the disadvantage that it is unable to discriminate between sharp bars and blunt bars, to which the time and pressure on the bed plate must be tuned. One has also the factor of variability of the stuff itself, which, even with

such regular products as wood pulp, is considerable at times. And last, but not least, the beaterman has to consult the requirements of the machineman as to length and wetness of stuff, etc. It is easy, therefore, to realize that no amount of minute instruction in the shape of text-book literature could teach a beaterman how to proceed in individual cases; these matters he can only become acquainted with by long practice in the mill. The author can only attempt a general discussion of the general principles upon which the theory and practice is based, in the hope that it may stimulate inquiry, and lead to a better order of things. Elsewhere the subject of composition of beater bars has been discussed, so that little attempt in these pages will be made to re-open this question, at least in so far as the use of different kinds of metals are concerned.

As a means of adjustment an attempt has been made to raise and lower the bed-plate, using hydraulic pressure. The idea appears to be a very plausible one, but it does not appear to have succeeded in its practical application. Provided that one is assured of absolute rigidity in bed plate and roll—a condition of affairs never entirely realized in practice, although more nearly realized now than formerly—and assuming that the beater-bars can be made to approach the bed-plate by easy increments of one-thousandth parts of an inch or even less, there is in the author's opinion no need to provide a cushion. In beating it would appear indispensable to place the roll-bars at a distance from the bed-plate bars equal to the diameter of the fibres under treatment, at least such should be the position during one stage of the beating. Here we should have a circumferential velocity of, say, 2000 feet per minute in a space clearance of only, say, $\frac{1}{1000}$ to $\frac{1}{4000}$ inch.

Even if such a state of things could be properly maintained in practice, there would in one sense be no clearance at all, because the fibres would more than take up the intervening space between the beater bars and the bed plate, and the rubbing action would be noticed. This can be exemplified in the following manner: The roll is set down so as to produce a rubbing effect in an engine of stuff nearly ready for the machine; without altering the position of the roll, the stuff is emptied just below the level of the bed-plate, when the rubbing noise ceases. If, now, some of the stuff remaining in the engine is by means of the paddle brought under the bed-plate, a grinding noise is produced, as if the surfaces were *brought* suddenly in contact. A less beaten stuff, *if brought in contact*, would make a louder grinding noise,

just as though the rolls had been brought in closer contact. If, therefore, the bars are brought *very* near the bed plate, but without being in actual contact, stuff brought between them will make more or less rigid contact between the two; and of course the amount of contact will depend upon the condition of the stuff at the time, as well as upon the actual microscopic space between the bars and upon other factors.

We have already referred to the *theoretical* travel of the stuff. The *actual* travel is complicated by other considerations than the mere admixture of the stuff. It is necessary to reckon with the retarding action or friction of the sides of the beater. This may occasion the stuff to stand still in places. This can often be observed when looking at the surface of the stuff in the beater. Very often a portion of the stuff will be observed to stand still at the rounded corner facing the front of the roll, and another at the diagonal opposite corner, from the fact that in the actual travel of the stuff it has a tendency to take short cuts, and so leave these areas undisturbed. These areas should be kept in motion by the use of a paddle or stirrer.

The rolls of many of the early beaters were provided with fly-bars placed at equal distances from one another. The beating power of a beater is dependent upon the number of fly-bars as well as the length of the bars. If 60 bars are placed round the roll at equal distances from one another there would not be sufficient space between the bars for the stuff to enter and to be driven forward properly. The effect is produced by placing them in clumps, usually of 3 or 4, with sufficient space between each clump for the stuff to enter and be propelled forward. In the case of a roll provided with 60 bars, if the clumps consist of 3 bars, there are, of course, 20 propelling bars, and if in clumps of 4, there are 15 propelling bars.

The effect of placing the bars in clumps is to give sufficient distances at regular intervals, so that the stuff may enter and be propelled by the front bar of each clump. If the bars were placed all at the same distance from one another, the narrow space between them becomes air-locked, so that the stuff cannot enter, and the propelling force of the roll is consequently reduced. The propelling force of a roll can be roughly estimated when the diameter of roll, the number of clumps, the distance they project, and the distance between them is known, provided, of course, that the spaces are filled with stuff; this, of course, is not usually so, as, for instance, early in the beating the stuff is sluggish and consequently does not draw readily under the roll.

The maximum power of propulsion can readily be arrived at from the number of revolutions per minute of a roll of known diameter, multiplied by the number of clumps, multiplied again by the area of space between each clump. The area of these spaces is got by multiplying together the distance the bars project by the distance between the clumps and the length of the bar. We can easily tell how much stuff the roll should carry forward per minute by these figures. If now we note the speed of travel by timing the rate of flow on the surface of beater in the middle, we can tell how much stuff actually does pass per minute. This data is of service in arriving at the efficiency of the Hollander as a circulator.

The practical papermaker is at once led to observe that the actual rate of circulation is far below that arrived at by calculations as above. One of the chief determining factors is the consistency of the stuff, and as this can be varied at will by regulating the amount of materials put into the engine or the concentration of the stuff, the papermaker has it very much in his power to control the rate of circulation by the manner in which he "furnishes" the engine. If very thickly "furnished," the circulation at the early stages of beating is extremely sluggish, so much so that it can hardly be said that the stuff is moving round the beater at all. All that is noticeable is a quiver or slight backward or forward motion on the surface of the stuff. The stuff receives by this means a more local beating, *i.e.* that stuff in immediate contact with the roll is well milled by passing perhaps a number of times over and under the roll before the next lot comes up to the roll for treatment.

By altering the number of bars in each clump and the distance between the clumps, etc., we alter the power of circulation. It must not be forgotten that it is useless to have more circulating power than is consistent with the natural flow round the beater. Any addition results in waste of power and unnecessary churning of stuff. With modern types of beaters which have other means of circulation, the fly-bars are arranged so as not to assist in driving the stuff forward.

On looking under the cover of the beater-roll it will very often be noticed that a lot of the stuff is brought right over the top by the roll and thrown down again in front. This, as will be hereafter seen, requires the expenditure of a lot of energy, and also retards the circulation by the wall of stuff that is thrown downwards. The rapid churning and agitation occasioned by the fly-bars, although wasteful, has a useful function, as it brings

about a change in the stuff which beating alone would not accomplish.

No doubt some change or changes take place in the stuff during the process of beating, which cannot be described as beating, bruising, or cutting, namely, a sort of wearing away of the outer surface of the fibres as in the case of cottons. As an instance, virgin cotton, such as cotton lint that has never been submitted to the chemical and mechanical processes preparatory to wearing, even after boiling and bleaching, behaves like so much slag-wool, and is almost devoid of felting properties ; in fact, even after thorough beating it would hardly be recognized as cotton pulp as we know the material when prepared from rags. By suitable beating, however, this material can be made to take on the ordinary qualities of cotton pulp. This change may be described as a wearing away or breaking up of the more resistant surface of the fibres, paving the way for the after-process of hydration or wetting of the fibres, which cannot be accomplished so long as the fibres remain intact and covered with a resistant coating.

Now, in regard to washing. An early method was to place a wire-screen in the cover of the breaker-roll just above the backfall, and against this wire screen the stuff is projected by the force of the roll ; in coming in contact with the screen much of the dirt was loosened and forced through the meshes. With certain dirty rags this method is a distinct advantage, but it is wasteful, as the energetic action of the roll driving the stuff against the screen, forces a quantity of fibre through as well as the dirt. The screens are sometimes used for the first part of the washing, and when the rags begin to get broken up the screens are shut off and the washing-drum is put into operation. The washing is now almost universally done by means of either octagonal or circular drums, which revolve partly immersed in the stuff. The form with eight sides helps in a measure to propel the stuff, as they strike the stuff on the surface at each of the angles and cause it to pass forward, but the drum most used is the circular form. The drum is placed so that the wash water does about three-quarters of a revolution in the breaker, passing under the roll in its way, before it is discharged by the drum washer. This gives the greatest amount of time before the water is drawn off the drum in front of the roll (as shown in Fig. 6).

The drum washer is generally covered with a backing of coarse wire, over which is stretched fine wire, about 60-mesh ; this depends upon what class of beating is being done. A coarse wire *is more efficacious in* getting rid of the dirt, but it permits the

smaller fibres to escape at the same time. These smaller fibres can be afterwards retained upon a save-all, and can be used up in the manufacture of lower classes of paper where presence of dirt is no detriment. With rag stock, where a very clean product is required, it is necessary to sacrifice some of the fibres in the process of washing. A fine wire will retain practically the whole of the fibres, but does not permit the coarser dirt to escape. The loss of fibre depends in a large degree upon the amount of suction exerted upon the wire of the drum. There are two ways of driving the drum; it is driven either by a small strap connecting with the spindle, or by means of a cog motion. The latter is preferable. The water is removed from the drum either by syphon or by buckets. The syphon is a pipe which enters the drum through one of its spindles, and has a trumpet-shaped end close to and across the lowest part of the drum. The other end of the syphon dips down to a point somewhat lower than the bottom of the drum, but on the outside of the breaker, so as to discharge into a drain.

The syphon is connected with the water supply, and has to be charged with water to start it. If properly regulated this will continue to work, but without proper care the syphon stops, and often this is not discovered until the water is overflowing the sides of the breaker.

The bucket drum is far preferable, as it requires no attention, and is now almost universally used. These so-called buckets are ranged inside the drum, somewhat like the fans of an air-propeller (as shown in longitudinal section, Fig. 5). They are divided into sections in such a way that the water in the bucket, as it reaches its highest point, is made to flow through a lip from the centre round the spindle of the drum down into the drain.

Breakers are generally painted to prevent them from rusting. The bars, both of the bed-plate and the roll, are, as a rule, made of steel; the roll-covers are made either of wood or zinc. Zinc is good material for the covers of certain high-class beaters, but it tends to promote galvanic action between the zinc and iron of the beater. Often a considerable amount of galvanic action takes place. I have seen with lead-lined beaters a very curious instance of accumulation of brilliant yellow chromate of lead through galvanic action, promoted by the zinc on the beater cover, in the presence of a certain amount of bleach and chrome mordanted rags. I constructed a small battery on the same principle, and found it had exactly the same effect. There is a certain amount

of galvanic action which more or less affects one or other of the metals. If chrome mordanted rags are brought in contact with a bleach solution, and placed between a sheet of zinc and lead, and the circuit completed by making metallic contact of lead and zinc by means of a wire, an electric current is produced, and lead chromate is deposited.

The bed-plate may be of either steel or bronze; sometimes the bronze bars are used in conjunction with bed-plates, and *vice versâ*. With the Hollander, although not with some forms of beaters, the beater-bars are bevelled on one side like a chisel, but have a slightly flat edge. The character of the beating will largely depend upon the extent of the edge of the beater-roll and bed-plate bars.

Sharp tackle is required for such paper as blotting paper; medium tackle for ordinary writing paper; dull tackle in conjunction with long beating for strong papers, such as linen banks.

Any one fibre, such as cotton or chemical wood pulp, can be made to produce an almost endless variety of effects by varying the conditions of beating—thus, both the above-mentioned fibres can be made to produce on the one hand soft, spongy paper, such as blotting and filter papers, and on the other hand transparent paper, such as banks and vellums: but it must be conceded that a material such as cotton lends itself more readily to the spongy effect, and the papermaker, consequently, by following the lines of resistance, naturally chooses cotton for soft papers.

The time of beating as well as the dulness of the tackle will be regulated by the strength as well as the wetness of the stuff, and consequently the shrinkage of the stuff on the machine; the stuff working "wet," assists the sizing qualities as well as the strength. Prolonged beating to some extent takes the place of adding size to the paper. Some stuff, working very wet as the result of beating with a dull tackle, on drying becomes transparent and very strong, and appears as well sized, from the fact of its having worked so wet, as an ordinary fibre would have been when engine-sized. Thus it will be seen that upon the mode of beating even the sizing qualities partly depend.

The beating is of very great importance from many points of view. Even the dandy-roll maker should know the condition of beating in the mill before he can calculate the distance of the water-marks, in order that he may allow for the necessary shrinkage. With an ordinary Hollander, working ordinary rag stuff, it may be taken as a general rule that one-half of the power consumed is used in promoting circulation, the rest is divided between

the friction of the engine as when running empty, and that absorbed in doing the actual beating.

It is a curious fact that when a Hollander is running with the roll off the bed-plate, but full of water, more power is consumed than if the water is replaced by thick stuff. I venture to think that many practical papermakers hardly realize this. This has been worked out and confirmed by two authorities. The reason of it is that the water comes right up to the front of the roll and is dashed about by rapid churning. When thick stuff is taken in place of clear water, if you lift the dash-board and look at the front of the roll, you will notice that the level of the stuff against the roll is very low, especially at the early stages of the beating. There is consequently not so much churning and dashing about, which occasions so much loss of power. With a thinner furnish, the level against the roll approaches nearer to that of water. It may happen that the thinner the furnish, the greater the power consumed. A great deal of power is wasted by the stuff dashing against the cover of the beater-roll, and a still further waste is occasioned by the stuff passing right over to the front of the roll again.

From the foregoing remarks, you will perhaps better understand Tate's Patent Beater arrangement, which intercepts the stuff which would otherwise be thrown back. By fixing a cone to the top of the back-fall so as to bring the back-fall to a much higher level, and by an alteration in the cover, so as to leave little or no space between the beater bars and the point of the cover directly above the back-fall, nearly the whole of the stuff is ejected through a fine passage, and becomes effective in promoting the circulation. The side walls being built up to a higher level, enable a Hollander to take anywhere from 25 to 50 per cent. more dry weight of furnish than it would otherwise do. This, although brought to a high perfection within the last few years, is not a new idea. It was roughly applied to the Korschoreign engine many years ago, but apparently without much success, on account of the imperfection of the structural details.

This arrangement is mentioned as increasing the scope of the Hollander. The author regarded it some years ago as being an important adjunct to the Hollander. It is doubtful, however, whether such an arrangement, except when ground space is limited, offers material advantages over the ordinary Hollander. For some reason or other makers seem to object to increasing the depth of a Hollander, except in the very large engines. Tate's *patent may be* said, in short, to increase the capacity of a

Hollander without increasing its output. The economy of beating is largely dependent upon output, and the output depends upon beating capacity. Unless the beating capacity of a Hollander is not improved without increasing the power consumption to a corresponding degree, then the economy of beating is not improved; and unless some important improvement is made in the character of the stuff, there can be no benefit in increasing the capacity of the beater. It must be noted that there is a distinction between "capacity of beater," which refers to the number of pounds dry weight that it will hold, and its beating capacity, which has to do with its output per hour.

I feel that good service could be done by the careful study of the Hollander, apart from any other form of beating, because the general principles hold good for most classes; and furthermore, the Hollander being in use more than any other form of beater, it would be more instructive to study the general principles of beating in connection with this form of beater, than with any other form either of beater or refiner now on the market. In spite of the various new types of beaters now in vogue, the Hollander is still holding its own for many purposes. For certain classes of rag beating it still has no rival. The relative merits of the Hollander and other types of beaters might well form the subject of a series of lectures and discussions.

Figs. 7 and 8 are views of the ordinary Hollander. Fig. 9 shows a Hollander with the beating rolls and washing drums.

CHAPTER I.

The economy of beating—The lines on which an enquiry into the subject might be conducted.

THERE will be no attempt to show the superiority of one beater over another in the tests recorded in the following chapters. In fact, it would be a great mistake to base such conclusions on any of these tests. They are cited with the object of establishing the general principles on which the theory and practice of beating is founded.

The desire is to make everything subservient to the subject of beating, and, as far as possible, to gather up the general principles from the fragmentary data that comes to hand. In order, however, to deal with the subject as a whole, or even extensively, much more data would be required. It would be dangerous to generalize from so limited an amount of information as is at the time of writing available.

The kind of information we may hope eventually to acquire is somewhat on the following lines :—The conditions which favour the beating of each class of stuff. Under "conditions" I would mention (1) time of beating ; (2) power absorbed per hour ; (3) type of beater ; (4) weight and size of rolls ; (5) number and position of bars on roll and bed-plate ; (6) composition of bars, and such like.

(1) and (2) might be considered together. It might be that a certain time is required for the performance of the beating, in which case it would be necessary to adjust the power to suit the time. A general impression has for a long time prevailed that it is necessary to beat for a given number of hours to obtain a certain result, and that time alone will do it. Certainly, time is an important factor ; but the time may, under certain conditions, be considerably diminished by changing one or other of the factors. *Supposing, for instance,* that the material of which the bars are *made is changed,* the time of beating may be either lengthened or

shortened. The result may be the same in the end, or it may not be possible to produce exactly the same result by other means.

With a Hollander, so much is dependent upon its form and size, and upon the size and weight of the roll. The exact shape of backfall will largely influence the rate of circulation. This point has already been referred to (see pp. 6 and 9). I have endeavoured to suggest what conditions favour the use of a Hollander. For materials such as strong rags, the Hollander is, I believe, able to hold its own against all comers. It must not be forgotten, moreover, that the breaking-in is almost always done in a Hollander, although the subsequent beating may be done in another kind of beater. But with materials requiring less beating, *i.e.* less expenditure of h.p.-h. per ton of stuff, a different mode of treatment is often found to be more economical.

The question of refining is an important one. As, for instance, how far with any given stuff the beating should be conducted before passing the stuff through the refiner. This is a question on which there are differences of opinion, and on which no settlement can be arrived at by papermakers except in so far as it suits their individual requirements. It would require very systematic work to throw material light on this point. It would be necessary to carry the beating up to a certain stage in the Hollander, ascertaining carefully the power required for a given output. When the partially beaten stuff was passed through the refiner, the power absorbed and output would also have to be ascertained. In another series, more work would be put on the Hollander and less on the refiner; and in a third series, less on the Hollander and more on the refiner, and so forth. But such work would belong to too advanced stages of the subject to be discussed in this volume.

The kind of information we want in regard to refiners is to know the power required for a given output, or the output for a given power consumption per hour. All machines work most economically at a given rate of output, just as a steam-engine or a dynamo is most economical at a given load. With a steam-engine we have the means of regulating the cut-off, so as to work under most economical conditions for a given load; but in a refining engine we are practically in the dark. A refiner must, I believe, work at a given rate of output to refine a ton of stuff with the minimum consumption of power. The output would depend, of course, upon the extent to which the stuff is to be refined, and the *kind of stuff under treatment*. There is, further, the question of *the proper thickness* of stuff to give the best result. We know

little on these points. We have no knowledge which we can tabulate, or formulate, or express in figures. Our knowledge, what little there is of it, is of the rule-of-thumb order.

One object of these pages is to stimulate inquiry, which it is to be hoped will result in further trials being conducted and tabulated.

There are other questions. Is it right to mix all the different fibres together in a beater, and beat together; or should they be beaten separately and mixed afterwards? There are reasons for and against mixing before beating; but how would it affect the power question? Is it right to beat "mechanical" with the "sulphite" for the manufacture of "news," or should the two be beaten separately, when the mechanical might be disintegrated separately and with much less power? Such questions as these, and many others, must always remain unanswered until the end of time, unless a carefully conducted series of trials are carried out, tabulated, and submitted to careful examination, and, if possible, to cross-examination, so as to make certain that no false conclusions are arrived at.

There are wide questions involved in the subject of beating. No attempt can be made in this book to answer any of these advanced questions; they are much better left in the hands of each individual papermaker. To give some rough ideas of what these questions are, and how the solution of them would help papermakers, is as much as can be attempted here. As we all know, there is a great deal of divergence between theory and practice—at least, so-called theory and present practice. Many of those who see this great divergence condemn theory as useless. It might be possible to state what theoretical amount of power is necessary, say, to reduce some particular raw material to half-stuff, and from half-stuff to beaten stuff. The difference between the amount of power necessary by theory, and that found to be necessary in practice, would appear most appalling. I think that the dynamometer diagrams, on p. 36, practically proves that the power consumed in the actual beating is very small; a much larger amount is consumed in friction between the bars of the roll and the bed-plate. The actual mechanical energy of brushing the fibres apart is little or nothing compared with the mechanical energy wasted in the friction of the bars against the bed-plate. Although much has been done to save power in regard to circulation, little has yet been done to devise a mode of beating which will not necessitate such a wholesale loss as is at present *occasioned* between the bed-plate and beater bars. In order that

an improvement may be made in this direction, we must first ascertain where the waste lies, and what gives rise to it.

I venture to think that it is at present hardly realized by many that the material of which the rolls are made is very likely to make a great difference in the cost of beating. I believe I am right in saying that certain materials are far more effective than others in drawing fibres apart, but there are peculiar difficulties in the way of using many of them. This part of the subject still requires much study and research.

It has been pointed out to me by a practical papermaker that the power consumption is of minor importance as compared with the result to be obtained, and that in the endeavour to save power the quality of the fibre is often sacrificed. This aspect of the subject must not, of course, be lost sight of; but for making many classes of stuff, the opposite is the case—namely, the less power expended the better the result, and of course with some classes of paper a substantial saving in power consumption is an important consideration. It must be borne in mind that with the results herein recorded no attempt is made to reduce the power consumption at the expense of the fibre. The results are all recorded under such practical and ordinary conditions as prevail in the mill. So that the figures represent average conditions under ordinary practice. As regards the relative importance of economy in beating, we may divide the beating roughly into two classes: (*a*) when the economy in beating is of secondary, and (*b*) when it is of primary importance; and in the instances to be cited, I think we may fairly say that these come under class (*b*). In the first part of this volume the subject is considered primarily from an economic and power-saving point of view; in fact, it is the main object of this volume. It is better to leave to the individual papermaker the consideration of the other point of the subject—namely, whether beating done under the most economic conditions would yield him the result he requires.

I think that it may be fairly stated that it is possible, with suitable tackle, to produce "wet" stuff in a much less time than is generally supposed, but that it is not possible to prolong the beating over a great length of time without producing wet stuff. I should like here to point out—since a certain amount of explanation appears to be necessary—that the results published in this volume can only be considered conclusive as far as the particular class of material and the conditions cited in the trials are concerned. Whether a certain type of beater would show the same advantage over another in point of economy and output on a different class

of material is another matter. We must leave any inferences of this sort to people's individual judgment; and if we do hazard a guess, we must put it forward merely as a speculation, and not as an assertion. It is quite possible that when we have a greater mass of data to work upon, that we may be able to prophesy correctly; but the unexpected does often happen even with beating.

Supposing, with a given beater, such as the Hollander—details of whose construction, etc., must be carefully noted—we were to conduct a series of trials to ascertain the amount of power necessary to beat 100 lbs. of different classes of raw materials, so as to compare the relative amount of power, time, etc., required by each. In order to carry the work on in a systematic manner, we should require to make a number of trials with each class of material, on the lines I have indicated, by means of a dynamometer, until we arrived in each case at the most economical conditions. This need not be a very long job, for, as the dynamometer gives us the readings as we go along, there is no waiting to work out results. We should soon see in what direction to work for economy. Having arrived at the most economical result, we could compare the different classes of stuff for consumption of power in beating. After that it could be definitely stated that such and such a material cost so much per ton to beat, and another material cost so much more or so much less, as the case may be. Now, if you go through the same cycle of operations with another class of beater, and then compare the whole of the results of the one with the whole of the results of the other, you can judge of the all-round advantages of the one as regards the all-round advantages of the other. But as regards the special advantages of the one as against the special advantages of the other—such as, for instance, the beating of esparto—it might happen that beater A would have an advantage over beater B. In the case of beating sulphite wood or rag fibre, the reverse might be the case—namely, that beater B showed economy in fuel consumption over beater A. Hence the necessity of arriving at conclusions only after a long-extended series of trials, and stating only what is true under carefully ascertained conditions.

I quite appreciate the force of the argument that the trials should be extended to all classes of beaters and stuff under the various conditions which appertain in practice. It would be possible then to arrive at really useful conclusions.

CHAPTER II.

Difficulties of arriving at definite results—Pressure of roll—Thickness of stuff—Behaviour of different fibres—Refining.

WE have so far considered the papermaker's beater *per se, i.e.* without taking into account the processes which precede and follow it. It has been discussed rather as an instrument in itself, without having regard to its surroundings. To trace the effect of the preliminary processes of boiling and bleaching, etc., upon the beating operations, as also the beating operation upon the behaviour of the stuff on the paper-machine and upon the finished or partly finished sheet would be to open up the whole subject of paper-making. As to those operations which precede as well as those which follow the beating operations, these have been discussed in their various aspects in previous volumes of this series, and further details will appear in regard to the character of the finished sheet in "The Fibrous Constituents of Paper." * All that is here needed is to show the connection with the subject of which this book treats, namely, "Beating," with the rest of the processes of paper-making.

The beater is regarded in this volume as a power-absorbing machine, and attempts have been made to measure the power consumption for different machines, and with different materials and at different mills. The author at the time that these investigations were originally undertaken had interviews both with the engineers who built the different kinds of beaters and also with papermakers, and every attempt was made to induce those interested to undertake trials somewhat on the lines already recorded.

It must be self-evident to those of my readers acquainted with the practical details of beating that this work does little more than touch the fringe of the subject. There has been no attempt to recapitulate a great deal of what has already been described by the author elsewhere, and by other writers upon the subject. The

* "*Technics.*" George Newnes, Ltd.

reader can for such purposes study the various text-books on papermaking, and, in so doing, he should not fail to refer to Continental authorities. A great deal, however, of what has been written is of a purely theoretical character, unsupported by any practical trials. The writer has attempted to emphasize this in previous publications, but, at the same time, has no desire to discount their value.

Discussions on problems connected with beating are, to say the least of it, liable to mislead unless they are based on considerable practical experience. The inductive methods of reasoning as applied to papermaking are without doubt the more valuable; of this I am convinced from having attempted both methods of reasoning. My early attempts were more properly arguments in which I entered into various discussions, but without much self-conviction. On the principle that an ounce of practice is worth a pound of theory, I sought afterwards for data from actual practice, and, after having collected some data, proceeded to draw conclusions from same, and attempted to see how far such conclusions, limited as they were, could be supported by data from further and more extended trials. It has taken five years to collect even such limited amount of data as this small book contains.

This book is given to the paper trade in the hope that these attempts to record results and to draw inferences from them will induce papermakers to make and supply further data, so that in course of time the practice of beating may be recorded as a scientific operation.

To those who attempt to calculate the beating capacity of any beater on a purely mathematical basis the task may appear to be a fairly simple one; but, to the practical papermaker, immediately an attempt is made to gauge the beating capacity of a beater on paper, many obvious difficulties present themselves.

The mathematician or theorist must of necessity start with more or less rigid assumptions. One must assume a definite quantity for the speed and weight of roll on bed-plate, also the angle that the bars of the bed-plate make with the bars of the roll, and a definite quantity for the capacity of the beater. So far so good, as such quantities can be fixed for the time being for any particular beater. But, in the ordinary Hollander, the variable factor of the wear of the bars has always to be contended with. The beating capacity—if one may use such a term—will depend among other things upon the thickness of the cutting edges, and this in turn depends upon the wear of the bars.

I *think it will* be conceded that the beating capacity depends, *among other things*, upon the pressure that the roll exerts upon

the bed-plate. Now, assuming for a moment that the weight of the roll upon the bed-plate is a constant quantity, the pressure will vary inversely as the area of the cutting edges; but as the area of the cutting edges varies (*i.e.* increases) from day to day with increased wear, the beating capacity will vary (*i.e.* decrease). But the pressure that the roll exerts upon the bed-plate is *not* a constant quantity, and is made to vary (*i.e.* increase) at different stages of the beating. The beaterman, as he lowers the roll from time to time, increases the weight upon the bed-plate, and even supposing that the roll can be put at one fixed point and left there (as is actually done in certain types of beaters and with certain qualities of stuff), the stuff alters in consistency during the beating, so that the weight that the roll exerts on the bed-plate also alters, and as the beating capacity depends among other things upon the weight of roll upon the bed-plate, so the beating capacity depends upon the consistency of the stuff. The character rather than the rate of beating may be, and undoubtedly is, affected by the rate as well as the mode of travel of the stuff.

It will be shown by actual figures that the rate of travel of the stuff varies at different stages of the beating, therefore it was thought that the beating capacity varies at different stages of the beating, and, among other things, with the rate of travel of the stuff. And the rate of travel of the stuff is in turn dependent upon the consistency of the stuff. From trials made on the Reed beater, it will appear that the view that the beating capacity varies with the rate of travel of the stuff does not hold good as far as the Reed beater is concerned, although under ordinary circumstances it may hold good in regard to the Hollander.

The question of thickness of furnish is, of course, of primary importance. Arguing on first principles, if a given beater is furnished "thin," *i.e.* containing, say, 3 per cent. fibre, 97 per cent. water, the fibres should be brought to the condition of beaten stuff in half the time required for stuff furnished "thick," *i.e.* containing, say, 6 per cent. of fibre and 94 per cent. water, that is, of course, if the beater in question is brought to the same level in the first instance. There are, however, other factors involved which may upset this simple calculation. Thus, by furnishing "thin," the consistency is different from the start, and consequently the rate of travel, and therefore the rate of beating may proceed at a different ratio. Therefore it does not necessarily follow that the thinner engine will be got off in exactly half the time. Furthermore, the two cannot be strictly compared, because the *character* of the *resulting stuff in the two* cases is different. By employing the roll

upon the thicker stuff, in which there is double the dry weight to operate upon, and consequently double the amount of beating to be done, it goes without saying that the beating will take longer. It is well known that the character of any stuff, say cotton or linen, depends upon the length of time involved in the beating—the longer the time the wetter the stuff. Therefore, with the thin "furnish" there is a tendency to the production of "free" stuff, and with a thick furnish, there is the tendency to produce "wet" stuff. Thus, for blottings where very "free" stuff is required, a very thin furnish is the custom (accompanied with sharp knives and angle plates to increase the cutting and beating capacity), and where wet stuff is required, for such papers as "banks," "loans," etc., the beater may be furnished thick; but as thickness alone would not decrease the rate of beating sufficiently, the roll must be let down more quietly, in addition to which the tackle (*i.e.* knives) should be dull, *i.e.* present considerable area. It can readily be seen, therefore, how these different factors are varied for the production of any particular effect.

Supposing, for instance, that a long free stuff is required, this may be produced by furnishing thin, so as to reduce the time of beating, but without letting the roll down too hard, but the time may be fairly short.

If a short free stuff is required, the same *modus operandi* as above, but the roll is brought down quickly, and the angle plates introduced to increase cutting effect.

The procedure for a long wet stuff has already been described. If a short wet stuff is required, the same can be produced by first getting a long wet stuff and then putting the roll down so as to reduce the length of fibre.

In rags, the time in the beater will depend upon the extent to which the stuff is reduced at the half-stuff stage. One paper-maker reduces his half-stuff more than another before the same is emptied into the beating engine. On visiting different mills, I have noticed considerable differences in this respect. Then, again, the extent of reduction in the beater will depend upon whether or not the stuff goes afterwards through a refiner, and again upon the length of fibre required for the paper machine, as well as the degree of "wetness" required, or amount of bruising to which the material has to be subjected.

With rags it may be said that, in some mills at least, there are twenty or thirty qualities, and each quality requires different treatment, and consumes different amounts of power *in its reduction.* On the other hand, the power required for

reduction from start to finish with a given class of rag or other fibre, for the production of a given kind of paper, is, however, a fairly definite quantity. It goes without saying that tender rags require less power for their reduction than strong rags. The ultimate fibre of, say, cotton may require, on an average, a fairly constant amount of power for its rending asunder if the fibre is new, but cotton rags of different qualities contain fibres of all stages of tenderness, and on the very tender rags the amount of power required to do the rending asunder must be only a small fraction of that required to rend asunder the virgin cotton fibres. Any attempt, therefore, to calculate the power consumption from the breaking strain determinations of individual fibres must, therefore, be no guide to what actually does take place in practice.

From the rag of known qualities to the finished stuff having a given average length of fibre, a fairly definite amount of power may be required. We have made numerous determinations of the average length of fibre of beaten stuff, in different mills, and the figures we regard to be of considerable importance to the paper-maker. These will be recorded in a subsequent chapter, in so far as they concern the subject of beating.

The other ingredients added to the paper-stock, such as loading and sizing, no doubt are not without their effect upon the rate as well as the character of the beating, but their influence is difficult to determine. Certain chemical substances affect the character and rate of beating. I have good reason to believe that considerable power might be saved if some chemical substance could be added. Thus we might, with good reason, expect that alkaline substances, such as caustic and carbonate of soda, would accelerate the beating and so enable the stuff to be got off with the expenditure of less power. We would expect, from what we know of the action of these alkalies upon cellulose, that the fibres would be drawn asunder more readily, and have a greater tendency to hydrate and work wet. There are, unfortunately, practical reasons against the use of such substances; among them may be mentioned the effect upon the colour of the stock, the liability to formation of froth, and the necessity of neutralizing the soda either by the addition of acid or alum, and, lastly, it would entail considerable additional expense. The addition of such substances as acid or alum during the beating would tend to brace up the stuff and promote free working. A systematic study of such chemical substances as aids to beating, if not for the saving of beating power, at least for the production of definite effects, might, I think, with advantage be studied in experimental plant.

The tensile strength of cotton fibres in the dry state has been studied for different kinds of cotton, but the force required to rupture the fibre under water, when the fibres are more or less hydrated and distended by the absorption of water, could not be calculated even for new cotton fibres, and no doubt varies at different stages of the beating, hence a purely theoretical attempt at arriving at such figures for power absorption could only end in failure.

The question of kollerganging might be considered as coming under the heading of beating; as this has been discussed at some length in previous volumes the subject need not here be considered. Readers might consult these references with advantage.*

The beating operation is also further complicated from the fact that beaten, or partly beaten stuff, or "broke," is added to the beater at different stages of the beating. As will be hereafter shown, the beater bars have a certain power of selection, that is, they act more upon some fibres than upon others. In a mixture of fibres of different lengths, or of different materials, mixed in one beater, it will be found, on careful microscopical examination of stuff at different stages of the beating, that certain of the fibres are reduced in preference to the others, so that so long as the more susceptible fibres are in the majority, the less suitable ones are, for the most part, left alone; but when the former have been sufficiently reduced, the beater bars divide their attention more uniformly among the different kinds of fibres present, when the further reduction proceeds in a more universal manner.

The two effects, namely, the separation and reduction of the fibres, are produced simultaneously. At the same time, other physical changes are determined by the action of the knives of the beater roll, resulting in the bruising and flattening of the ultimate fibres, and, in many cases, their further reduction, as by splitting longitudinally into smaller units, or fibrillæ. Where the beating is carried to extreme limits, as is frequently the case for high-class rag papers, such as bank-note and cigarette papers, many of the individual or ultimate fibres are beaten out of all recognition.

The manner in which the fibres become separated and mechanically reduced is determined, not only by the methods of beating employed, but equally by the structural characteristics of the fibre acted upon. In this matter, each class of fibre has certain

* "Chapters on Papermaking," vol. iii. pp. 102, 103, 122-129; vol. iv. p. 8.

characteristics which can, in some measure, be foreshadowed by a careful study of literature devoted to the subject.*

The extent to which the ultimate fibre may have to be subdivided will depend, of course, upon its initial length. Thus, straw-pulp fibres are already so small, both in length and diameter, that they mostly escape disintegration. The esparto fibre, being somewhat longer, is occasionally cut asunder. On account of the smooth and flattened nature of the wood fibre, it is less frequently cut or bruised than might be expected. Very strong linen banks and similar papers contain beaten fibres with an average length of 3 mm. to 5 mm. After the most strenuous care has been exercised to draw out the fibres without cutting them asunder, they are found to be cut, on an average, into about six pieces. It is impossible, in the case of linen, hemp, and cotton, by any ordinary beating process, to separate the fibres without disintegrating them.

For strong papers it is necessary to avoid a cutting action as far as possible, the disintegrating or rending asunder being brought about by bruising and breaking, giving to the ends of the fibres a broken, splayed, or tangled appearance, which adds to their felting or strength-giving qualities.

Cotton is split, by the bruising action of the roll at the point of rupture, into fibrillæ, showing an interlacing network or trellised appearance; but linen, on the other hand, is split into a bundle of longitudinal fibrillæ, forming often a paint-brush-like end. Such deformation of fibres largely increases their strength-giving and felting qualities. On the other hand, if the beating is conducted so as to give a clean cut at the edge, the fibres produce papers of inferior strength, due to their inability, when interlaced, to grasp one another.

A further change takes place in the fibres as the result of their contact with the watery medium; the continual beating and agitation causes the cell-wall of the fibre to absorb water and pass into the condition of a gelatinous hydrate. In proportion as this change is effected, the stuff is said to work "greasy" or "wet," an effect which may be regarded as due to a solution of water by and in the cellulose (hydrate).

Some celluloses are more susceptible of these changes than others; thus linen pulp always has a greasy feel, and for this reason can be distinguished in the hand by the beaterman from cotton, which has not the same tendency.

For the production of strong papers, prolonged beating may

* "*Papermaking*," chap. iv. Cross & Bevan.

be essential, not only in order that the fibres may be drawn out, but to produce this gelatinous effect, which is a matter of time. If half-stuff is beaten for a period of, say, from 40 to 150 hours, its condition approximates to that homogeneous, gelatinous mass which is obtained by the spontaneous setting of solutions of the sulpho-carbonates. This product, by draining, pressing, drying, and moulding, was used as structural material, and known as cellulith. This may be regarded as the extreme product resulting from prolonged beating.

The factor of pressure of roll on bed plate is one of considerable importance. This may be roughly calculated when the weight of the roll and the superficial area of the bars of bed-plate are known. Thus, with a given number of foot-cuts per minute must be taken into consideration the pressure in pounds per square inch that the roll exerts upon the bed-plate, in order that the beating capacity may be arrived at. But it cannot be said that the beating capacity is in direct proportion to the pressure of the roll, and, seeing that the result to be achieved varies enormously with particular requirements, limiting the pressure that may be exerted, the mathematical treatment of the beater is liable to the danger of leading to unwarrantable conclusions.

The word "beating" is, perhaps, hardly descriptive of the various processes or treatments involved in the reduction of fibrous materials, and, perhaps, no comprehensive term can be found for these several processes. These vary from actual cutting of the fibres in the manner of a pair of scissors to that of bruising and crushing, and between these two extremes we have the mere drawing out or separation of ultimate fibres, the flattening as by rolling and splitting into fibrillæ. All these different processes are involved in every case of beating, although the conditions of beating, as well as the nature of the material, assist to determine which is to predominate. The mechanics of beating is, therefore, complex, and incapable of scientific treatment, in so far that it does not lend itself to any form of numerical expression.

"*Refining*" *and Refiners.*—The operation of refining as originally conducted, and as generally practised at the present time, is used for clearing the stuff, *i.e.* performing just that operation which is ordinarily conducted in the beater when the roll is lifted and made to brush out the stuff just before emptying. In such cases only a small amount of the power is expended in the refining operation.

It has become the practice in some mills to put an increasing

amount of work upon the refiner, and, consequently, less upon the beater.

The "Jordan," "Horne," and "Marshall" refining engines consist essentially of a hollow cone, provided internally with fixed bars, in which rotates a solid cone provided with bars; the stuff passing between these bars is brushed out. If a small amount of brushing or clearing only is required, the stuff is passed rapidly through, the reduction being controlled largely by the flow, but also by the pressure of the revolving bars against the fixed bars. Like Hollanders and other types of beaters, there is a certain rate of output and pressure on bars which will perform the necessary brushing out with a minimum expenditure of power. The specific action of these refiners depends to a large extent on the fact that the circumferential velocity increases from the inlet at the narrow end to the outlet at the wide end; thus the fibres pass through under a tension which is said to tend to draw them out straight and parallel.

With certain forms of beaters it is possible to adjust the roll at a constant elevation with just the right pressure of roll on bed-plate to give a satisfactory as well as an economical result. Such a mode of beating can be applied to the short-fibred half-stuffs, such as straw, esparto, and some forms of wood-pulp.

The introduction of the electric drive has rendered it possible to take records of the power consumption of individual beaters, which by the older methods of taking indicator diagrams was not possible. Now that the papermaker can see at a glance, at any moment, what his machines are individually absorbing, satisfactory progress is being made in the direction of more stringent economies; nevertheless, much remains to be done in this direction.

In the beating operation proper, when first the engine is furnished, the roll is, to use the current expression, "put down light" for half an hour or so. The beaterman then gradually lowers the roll on the bed-plate until, towards the end of the beating, the roll is "hard down," which may mean that it is exerting the pressure of its full weight. Ten minutes before emptying, the roll is lifted somewhat to clear or "refine" the stuff.

A large proportion of the power necessary for driving a paper mill is absorbed in the beater-house, consequently any economies that can be effected in this department deserve particular study. Such economies can only be effected when the nature of the power consumption is properly understood. Useful information can be gleaned from diagrams of the power absorbed.

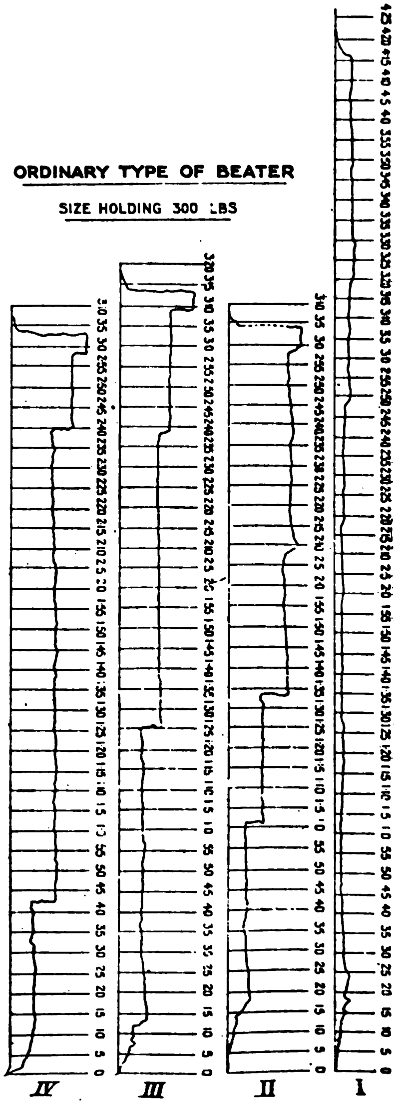
CHAPTER III.

Power consumption at different stages of beating as recorded by dynamometer diagrams.

I HAVE on one or two occasions given it as my opinion that there is a great deal yet to be learnt in regard to beating from an economic point of view. What do we really know about the power absorbed at different periods of the beating? and what do we know about the necessary expenditure of energy for beating different classes of stuff?

The science of electricity is only an infant in years as compared with the art of papermaking, and yet electrical engineers have so much reliable *data* at their disposal that they can, in estimating for any installation of electric plant for tramways or electric light, tell us just what loss we shall sustain through leakage of electric current. They can guarantee to within 1 per cent. or less of their estimates. Engineers have to tender for dynamos of a certain efficiency, such as 92·5 per cent.; in the event of the efficiency falling below this, a deduction is made of so much for every 1 per cent. below efficiency as tendered. The same mode of tendering is now applied to steam-engines. This is all because the sciences of electricity and engineering are so thoroughly well understood, even in many of their minute details. The advantages of a thorough knowledge of an industrial subject cannot be over-estimated, and as time goes on and manufacturers are compelled to look to anything and everything that will lead to further economy, they eventually, and perhaps as a last resource, seek the aid of science.

Can we by any scientific treatment of the subject add to the efficiency of a beater, and so save something on our coal bill? This is the question we will study. For the information contained in this chapter and the next, I am indebted to Messrs. Thomas and Green, of Soho, Bucks., and also to Messrs. Edward *Lloyd, Ltd., of Sittingbourne*, who have given me carte blanche



to publish diagrams and tables as the results of trials that were conducted at their respective works. I am also much indebted to Mr. A. Masson, of Messrs. Masson, Scott and Co., Ltd., for the assistance he has given me. The diagrams and results of trials with beaters are entirely the work of the above-mentioned paper-makers. These firms are, however, in no way responsible for the summaries and analyses I have made of the results, nor for the conclusions I have come to in reference to the same. For these latter, I hold myself entirely responsible.

The first set of trials took place at the works of Messrs. Thomas and Green, the object being to determine the amount of power absorbed by the actual beating and circulation. The instrument used for recording the results was Masson's dynamometer. This instrument automatically records on a card the horsepower by means of a movable pointer. On examination of the card, taken at the finish of the beating, it was possible to see at a glance the horsepower absorbed during every minute of the operation. The horizontal

straight line at the base of each diagram represents the zero point. This is the line the pointer would have touched if the beater had been running empty. I must point out that, in order to ascertain the *total* amount of power consumed by each beater, it is necessary to add to the amounts shown on these diagrams the power required to run the beater when empty, and with roll up. This can be ascertained for any beater by a blank experiment; and as the amount of power is practically a constant quantity, the power so determined can be painted on the beater, if necessary. To return to the dynamometer diagram, it will be noticed that there are a number of vertical lines at equal intervals, these represent periods of five minutes. At points where the vertical lines cut the wavy line made by pointer, the horsepower was read off. These figures are given in the subjoined table. In my summary of this table I have calculated the mean horsepower during each trial by adding up the five-minute readings and dividing by the number of readings. To arrive at the number of "horsepower-hours," I have, of course, multiplied the average horsepower by the duration of the trial in hours, as shown in my summary.

ORDINARY TYPE OF BEATER (HOLLANDER).

Details of Manipulation of Beater in each Case.

DIAGRAM I. (p. 36).	H.	M.
Start empty	0	0
Fill in (roll down)	0	15
Shut	0	20
Started	0	30
Shut	0	35
Started	0	40
Roll on harder	1	25
Put in some doctors	2	50
Roll on harder	3	20
Roll off	4	20
Empty	4	25

DIAGRAM II. (p. 36).	H.	M.
Start empty	0	0
Fill in (roll down)	0	20
Roll down harder	1	5
" "	1	35
" "	2	10
Roll up	3	5
Empty	3	10

ORDINARY TYPE OF BEATER (*continued*).

Diagram III. (p. 36).

	H.	M.
Start empty	0	0
Fill in (roll down)	0	20
Roll down harder	1	30
" "	2	40
" hard down	3	10
Roll up	3	15
Empty	3	20

Diagram IV. (p. 36).

	H.	M.
Start empty	0	0
Fill in (roll down)	0	14
Roll down harder	0	40
" "	2	40
Roll up	3	5
Empty	3	25

FIGURES DERIVED FROM HOLLANDER DIAGRAMS (p. 36).

Times of beating, from start. hrs.	mins.	Nos. 1. h.p.	2. h.p.	3. h.p.	4. h.p.
0	0	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	0
0	5	1	$\frac{1}{4}$	$1\frac{3}{4}$	3
0	10	2	1	2	$3\frac{1}{4}$
0	15	3	$2\frac{1}{2}$	4	$3\frac{3}{4}$
0	20	3	$3\frac{3}{4}$	$3\frac{3}{4}$	$3\frac{3}{4}$
0	25	$3\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{3}{4}$	$3\frac{3}{4}$
0	30	3	$3\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{3}{4}$
0	35	3	$3\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{1}{2}$
0	40	$2\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{1}{2}$
0	45	$2\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{3}{4}$	6
0	50	2	$3\frac{1}{2}$	$3\frac{3}{4}$	6
0	55	2	$3\frac{1}{2}$	$3\frac{3}{4}$	6
1	0	2	$3\frac{1}{2}$	$3\frac{3}{4}$	6
1	5	2	5	$3\frac{3}{4}$	6
1	10	$2\frac{1}{4}$	$5\frac{1}{4}$	$3\frac{3}{4}$	6
1	15	$2\frac{1}{4}$	$5\frac{1}{4}$	$3\frac{3}{4}$	6
1	*20*	$2\frac{1}{4}$	5	$3\frac{3}{4}$	$6\frac{1}{4}$

HOLLANDER DIAGRAMS (*continued*).

Times of beating, from start. hrs.	mins.		Nos. 1. h.p.		2. h.p.		3. h.p.		4. h.p.
1	25	...	2¼	...	5	...	3¾	...	6¼
1	30	...	2½	...	5¼	...	5¾	...	6¼
1	35	...	2	...	9	...	5¾	...	6
1	40	...	2¼	...	9	...	5¾	...	6¼
1	45	...	2	...	9	...	5¾	...	6¼
1	50	...	2	...	8½	...	6	...	6¼
1	55	...	2	...	8½	...	5¾	...	6¼
2	0	...	2	...	8½	...	5¾	...	6½
2	5	...	2	...	8	...	5¾	...	6¼
2	10	...	2	...	11	...	5¾	...	6¼
2	15	...	2	...	10	...	5¾	...	6¼
2	20	...	2½	...	9¾	...	5¾	...	6¼
2	25	...	2¾	...	10	...	5¾	...	6¼
2	30	...	2¾	...	10	...	5½	...	6¼
2	35	...	2½	...	10	...	5½	...	6¼
2	40	...	2½	...	10	...	6½	...	9½
2	45	...	3	...	10	...	6¾	...	9½
2	50	...	3½	...	9½	...	6¾	...	9½
2	55	...	3¼	...	9	...	7	...	9½
3	0	...	3¼	...	13¼	...	7	...	13½
3	5	...	3¼	...	3	...	8	...	2
3	10	...	3¼	...	0	...	13½	...	0
3	15	...	3¼	...	—	...	—	...	—
3	20	...	3½	...	—	...	—	...	—
3	25	...	3¾	...	—	...	—	...	—
3	30	...	3½	...	—	...	—	...	—
3	35	...	3½	...	—	...	—	...	—
3	40	...	3½	...	—	...	—	...	—
3	45	...	3½	...	—	...	—	...	—
3	50	...	3½	...	—	...	—	...	—
3	55	...	3½	...	—	...	—	...	—
4	0	...	3½	...	—	..	—	...	—
4	5	...	3½	...	—	...	—	...	—
4	10	...	3½	...	—	...	—	...	—
4	15	...	3½	...	—	...	—	...	—
4	20	...	1	...	—	...	—	...	—
4	25	...	0	...	—	...	—	...	—

The next step is to take into consideration the output of the beaters as well as the average horsepower. We have in each

trial a certain output in pounds of dry beaten stuff, at the expense of a known expenditure of energy expressed in "horse-power hours": from this I have calculated the "horsepower-hours" per 100 lbs. of stuff. This figure represents an absolute measure of power consumed, and by means of this figure one trial can be compared with another. It will be noticed that when the diagrams are held the right way up the figures read from right to left. The diagrams on p. 36 should be compared against the corresponding figures on pp. 37 to 39. If trouble is taken to measure the vertical distance on diagram from base-line to wavy line, for the different horsepower figures, as shown in the table, it will be found that there is not a uniform elevation per horsepower. The value of the reading of the instrument depends, however, upon the fact that the instrument was checked against actual horsepower determinations. If there should have been any slight error in the instrument, it would have applied to all diagrams alike, and, therefore, the diagrams are comparable one with another.

I should like here to point out the value of such an instrument in enabling a papermaker to arrive at the most economical condition of beating, say, when beating with a Hollander. He may have a battery of eight Hollanders, driven by a steam-engine. If, now, he indicates the engine with all beaters running empty, and divides the figure by eight, he will know once and for all the total power consumption for running his beaters empty. If he employs a self-recording dynamometer, he can, by a series of trials—which need not, as far as I can see, interfere with the regular work of the mill—find out the conditions which will favour the least consumption of power per 100 lbs. of stuff beaten. He may find that in order to beat with the least expenditure of energy he should have ten beaters instead of eight, and beat the stuff longer, or he may find that he should force the beating a little more, and use six beaters instead of eight. In the two cases the character of the stuff may be different, but it is to be presumed in all cases when comparative trials are made, that the beating is carried to one standard of length.

Glancing at the summary of Hollander tables (pp. 38 and 39), it will be noticed that when beating is spread over 4 hours 25 minutes the average horsepower can be kept down to 2·66, giving a consumption of power per 100 lbs. of stuff of 3·919. When the beating is conducted in 3 hours 10 minutes, the mean horsepower is almost doubled, resulting in an expenditure of *power of 6·731 h.p.* per 100 lbs. of stuff beaten. It must not be

forgotten, however, that when the initial horsepower is added to these figures, the result would be modified. The figures give the actual expenditure of energy for beating and circulation, to which must be added in each case the initial power required to drive the beater and overcome friction of engine and shafting. It will be noticed that the rapid rise in Diagrams II., III., and IV. corresponds with the time when the roll was put down. Furthermore, it will be noticed that putting the roll down harder, as in the ordinary course of beating, at once often adds 4 h.p.

There is another point which appears fairly evident from a study of these diagrams—and that is that the great bulk of power is due to the friction of the fly-bars against the bed-plate, and not in the actual beating. The actual beating force—*i.e.* force necessary to draw and cut the fibres—appears to be a very small proportion of the total force expended. Notice that when the roll is lowered at any period during the beating there is an almost vertical rise. The pointer then proceeds in a fairly horizontal line, until the roll is further lowered. If the beating *per se* requires a considerable proportion of the energy, apart from the friction of the bed-plate, one would expect to find that the line would gradually fall as the beating and the fibres became reduced, and until further pressure is put upon the roll. If, however, one looks at beater diagram No. IV., it will be noticed that for a period of two hours the roll was not lowered, during the whole of which time the power remained practically stationary.

There is another question, already referred to, which might in a measure tend to complicate this issue. As already stated, it has been shown by a Continental authority that the power absorbed in circulation and agitation is greatest when the beater contains only water, and is much less when a beater is furnished with thick stuff. The reason of this, to my mind, is clear. The water finds its own level quickly, and is high up against the roll; whereas thick stuff is drawn right down to a low level, and does not hamper the motion of the roll nearly so much. It would follow, then, that as the stuff got more beaten the power required for circulation would increase in consequence of the stuff resuming more nearly the fluidity of water, and consequently finding a higher level against the roll. What we should expect, then, if the beater-roll were kept stationary for some time, would be that the power absorbed in agitation would increase and the power absorbed in actual beating would diminish. The one might well neutralize the other, so that the power of the beater remained constant

until the roll was again lowered. These points require further investigation.

Turning to the diagrams for the Taylor beaters, p. 43, we find different dynamometer curves. They are more wavy, but on the whole much more gradual in their ascent. When the roll is lowered, there is here little indication of it on the diagrams. In some kinds of stuff, the roll of a Taylor beater can be practically set at one position for the whole of the beating. Of course, with a Taylor, there is a far more regular circulation throughout the beating, whereas, with a Hollander, the circulation starts almost at *nil*, and increases as the stuff gets thinner. Furthermore,

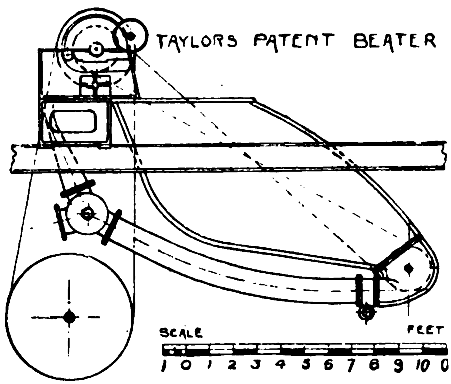


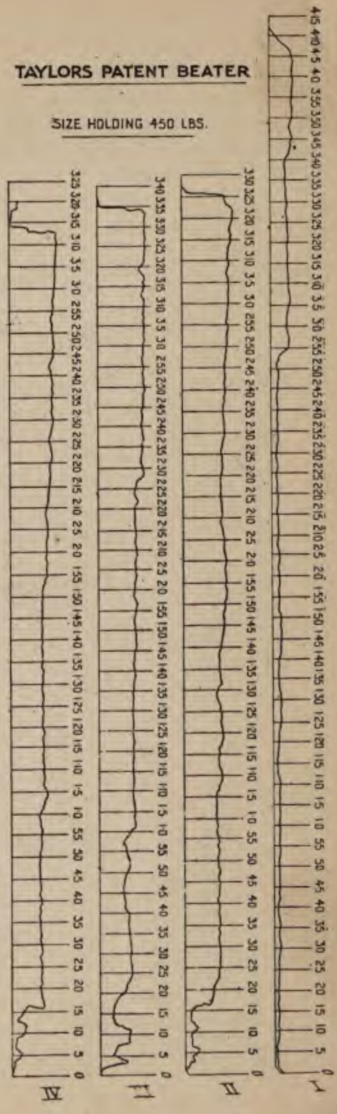
Fig. 10.

with a Taylor, the power required for circulating should be somewhat greater at the commencement, in consequence of the stuff being at its maximum thickness; but, as time goes on, and the stuff becomes thinner, due to the beating, the power required to enable the agitator to throw the stuff is presumably somewhat lessened. We therefore see that, both in the change in rate of flow and change in power to promote the flow, the Hollander and Taylor differ from one another.*

* The above observations were advanced at the time the trials in Taylor beaters were tabulated. Since that time a series of researches on the rate of beating as measured by the diminution in the length of fibres have been conducted. These clearly indicate that even with the Hollander, the rate of reduction in length of fibre at the early stages of the beating is far greater than at the lath and final stages. In this

But an alteration in the rate of flow must also effect an alteration in the rate of beating at different stages of the beating. It might have been assumed that the rapidity of beating increases with a Hollander as the beating proceeds, in consequence of the circulation increasing. With a Taylor, the circulation being kept more uniform throughout the whole of the beating, the beating should be conducted more uniformly. The question of power must, in some measure, be influenced by the number and position of fly-bars and bars of bed-plate. With a Hollander, we are compelled to place them in clumps, and the clumps must be a sufficient distance apart to act as paddles in promoting circulation; but in the case of the Taylor, where the circulation is promoted by other means, the bars can be differently placed, and placed in such a way as to ensure the greatest efficiency in beating, without having regard to the question of circulation. Bars placed at regular short intervals round a roll coming in contact with bars placed closely in the bed-plate, I think it is generally conceded, absorb less power relative to the beating capacity than bars placed in clumps with considerable spaces between. A fresh set of circumstances come into play, therefore, in an engine

chapter, however, we are not regarding the subject from point of view of *length of fibre.*



like the Taylor. I wish it to be understood that I mention the Taylor in comparison with the Hollander in the comparative tables, because we have before us these particular dynamometer diagrams for consideration; but the above general observations apply—in a measure, at any rate—to all beaters in which the circulation is promoted by some independent agency, and in which the bars are similarly placed.

FIGURES DERIVED FROM TAYLOR DIAGRAMS (p. 43).

Times of beating, from start. hrs.	mins.	Nos. 1. h.p.	2. h.p.	3. h.p.	4. h.p.
0	0	0	½	½	½
0	5	1	2½	3	2
0	10	1	2	4¾	3
0	15	1	1½	3¼	3
0	20	1	4¾	3½	4¾
0	25	1¼	5¼	4¾	4¾
0	30	1½	5¼	5	4¾
0	35	1½	5¼	4¾	4¾
0	40	1½	5¼	4¾	4¾
0	45	1½	5½	4	4¾
0	50	1¾	5¼	4¾	4¾
0	55	2	5¼	4¾	4¾
1	0	2	5	4¾	4¾
1	5	2	5	5½	5½
1	10	2	5¾	5¼	5½
1	15	2	5¾	5¼	5½
1	20	2	5¾	5¼	5½
1	25	2½	5¾	5¼	5½
1	30	2¾	5	5½	5½
1	35	2	5½	5½	5¼
1	40	2	5½	5¾	5¼
1	45	3	6	5¾	2¼
1	50	2½	6¼	5¾	5¾
1	55	2¼	6¼	5¾	5¾
2	0	2	6¼	5¾	5¾
2	5	2¼	6	5¾	5¾
2	10	2	5¾	5¾	6
2	15	2	5¾	5¾	6
2	20	2	5¾	5¾	6

TAYLOR DIAGRAMS (*continued*).

Time of beating, from start. hrs.	mins.	Nos. 1. h.p.	2. h.p.	3. h.p.	4. h.p.
2	25	2	$5\frac{3}{4}$	$5\frac{1}{2}$	$6\frac{1}{4}$
2	30	2	6	$6\frac{1}{4}$	6
2	35	2	6	$6\frac{1}{2}$	$6\frac{1}{4}$
2	40	2	$6\frac{1}{4}$	$6\frac{1}{4}$	$6\frac{1}{4}$
2	45	2	$6\frac{1}{4}$	$6\frac{1}{2}$	$6\frac{1}{4}$
2	50	$2\frac{1}{4}$	$6\frac{1}{2}$	$6\frac{3}{4}$	$6\frac{1}{4}$
2	55	$3\frac{3}{4}$	$6\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{2}$
3	0	$3\frac{3}{4}$	6	$6\frac{1}{2}$	$6\frac{1}{2}$
3	5	$3\frac{3}{4}$	$6\frac{1}{2}$	$6\frac{3}{4}$	$6\frac{1}{2}$
3	10	$3\frac{3}{4}$	$6\frac{3}{4}$	7	$6\frac{3}{4}$
3	15	$3\frac{1}{2}$	7	7	1
3	20	$3\frac{3}{4}$	$7\frac{3}{4}$	$6\frac{1}{2}$	3
3	25	$3\frac{1}{2}$	$6\frac{1}{4}$	$6\frac{3}{4}$	—
3	30	$3\frac{3}{4}$	—	$6\frac{3}{4}$	—
3	35	$3\frac{3}{4}$	—	$3\frac{1}{2}$	—
3	40	$3\frac{1}{2}$	—	—	—
3	45	4	—	—	—
3	50	4	—	—	—
3	55	$4\frac{1}{2}$	—	—	—
4	0	$4\frac{3}{4}$	—	—	—
4	5	$4\frac{1}{4}$	—	—	—
4	10	2	—	—	—
4	15	0	—	—	—

DETAILS OF MANIPULATION DURING BEATING FOR THE TAYLOR BEATER.

DIAGRAM I. (p. 43).

	H.	M.
Start empty	0	0
Fill in (roll down)	0	15
Roll down harder	1	30
„ „	2	50
Roll up	4	10
Empty	4	17

Diagram II. (p. 43).	H.	M.
Start empty ...	0	0
Fill in (roll down)	0	20
Roll down harder	1	20
" "	2	10
" "	2	26
" "	3	10
Roll up	3	5
Empty	3	30

Diagram III. (p. 43).	H.	M.
Start empty ...	0	0
Fill in (roll down)	0	20
Roll down harder	1	2
" "	2	30
" "	2	40
Roll up	3	28
Empty	3	35

Diagram IV. (p. 43).	H.	M.
Start empty ...	0	0
Fill in (roll down)	0	15
Roll down harder	1	5
" "	2	25
* Agitator stopped	3	10
Roll up	3	15
Empty	3	22

Dynamometer records would, I think, assist us in forming some better opinion upon the economic value of certain structural details and modifications in the Hollander, upon which much difference of opinion still exists. It is hardly within the province of this volume to discuss these details, and at best I could do no more than speculate as to how far such structural details might affect the cost of beating. If these chapters should be the means of giving engineers and papermakers useful ideas I should feel that the publication of them would be fully justified. No work

* See p. 70.

has so far been done by the aid of dynamometers. Such work remains open as one of the useful fields of industrial research of the future.

SUMMARY FROM DIAGRAMS AND TABLES AS GIVEN ON PP. 36–39, 43–45.

	1	2	3	4
DIAGRAM.	Duration of trial expressed in decimals.	Mean horse-power during trial.	Horsepower-hours per beater.	Horsepower-hours per 100 lbs. of beaten stuff.
HOLLANDER, No. 1	4·42 hrs.	2·66	11·757	3·919
,, ,, 2	3·16 ,,	6·39	20·192	6·731
,, ,, 3	3·33 ,,	4·94	16·450	5·483
,, ,, 4	3·16 ,,	5·88	18·580	6·193
Mean Nos. 1–4	3·52 hrs.	4·97	16·745	5·581
TAYLOR ... No. 1	4·28 hrs.	2·45	10·486	2·330
,, ... ,, 2	3·50 ,,	5·44	19·040	4·231
,, ... ,, 3	3·58 ,,	5·50	19·690	4·376
,, ... ,, 4	3·33 ,,	5·17	17·216	3·826
Mean Nos. 1–4	3·67 hrs.	4·64	16·608	3·691

Turning now to the above summary of diagrams, with the Taylor, as with the Hollander, the prolongation of the beating has resulted in a much lower figure for the h.p.-hours per 100 lbs. of beaten stuff, for the power consumed for the beating and circulation. It will be seen, therefore, that the time factor is a most important one, from an economic point of view. As with the Hollander, a period of time must be arrived at with the Taylor, for a given class of stuff, during which the beating would be effected with the least expenditure of fuel. If the determination of this would only effect ten per cent. saving of power in the beater-house, it would be well worth the while of the papermaker to ascertain it, and see that the most economical conditions are fulfilled. In order to do this, I am inclined to think that he should have a suitable dynamometer as a permanent attachment in the beater-house. He is bound to have a pressure-gauge fitted to his steam-boiler, and every one realizes the necessity for this. I venture to *think that it will* be realized some day that for the purpose of

beating under the most favourable and economic conditions, a dynamometer as a permanent attachment to the beater will be as necessary as a pressure-gauge is to a steam-boiler. Of course, the necessity for the use of a dynamometer does not so much arise when the beater is electrically driven, as is the case in several of the cases cited later in this work.

In the summary of diagrams on p. 47, it will be noticed that I have calculated the mean of the four results from the Hollander diagrams, and also the mean of the four results from the Taylor diagrams. It so happens that the mean time in each case is almost identical; but in the case of the Hollander the mean horsepower expended is somewhat higher than in the case of the Taylor. As, however, the Hollanders have a capacity of 300 lbs., whereas the Taylor beaters have a capacity of 450 lbs., there is a considerable difference between the two in the amount of power expended in the circulation and beating. The Hollander has consumed, on the average of the four trials, 5·581 h.p.-hours per 100 lbs. of beaten stuff, whereas the Taylor beater has consumed only 3·691 h.p.-hours per 100 lbs. of stuff.

From a theoretical point of view, it must be conceded that the beating should be effected, if possible, without actually bringing the fly-bars in contact with the bed-plate. The space between the two should be almost infinitesimal, and perhaps no greater at the close of the beating than the diameter of the fibres. It has been found extremely difficult to accomplish this in practice, but it certainly should be aimed at as far as possible. There are certain practical difficulties in the way of accomplishing this, but in proportion as these difficulties are removed, we shall be able to approximate closer to what theory dictates. One of the main difficulties is that the beater roll is not absolutely rigid; it vibrates somewhat in the course of its rotation, thus preventing us from ensuring an absolutely uniform distance between the surfaces of all the bars and that of the bed-plate. The bars themselves get worn more or less irregularly, and the same is true of the bed-plate. In order, therefore, to bring the whole of the surface of the fly-bars in sufficient proximity to the bed-plate, some portions must of necessity be rubbing very hard, so wasting an immense amount of power. In addition to this, the adjustment of the roll is not sufficiently sensitive, and, furthermore, we have no means of ascertaining the exact distance of the fly-bars from the bed-plate. We can only tell that they are touching, more or less, from the *vibration.* In order to control the distance of the roll from the *bed-plate with any* degree of exactness, it is necessary to have a

very heavy and rigid roll, as well as a fine adjustment. In beaters of modern type, however, we are approaching nearer to the accomplishment of this. A friend of mine has had a beater constructed with a microscopic adjustment which he can regulate with the greatest possible nicety. When a beater can be constructed for practical work which can do the beating without more contact between the fly-bars and the bed-plate than is absolutely necessary, we shall have much more economic beating than we have at present. There is another point which requires careful study. In ordinary beating with the Hollander, as at present conducted, the roll is lowered three or four times during, say, a corresponding number of hours' beating. Would it not be much more economical if the roll could be lowered at much more frequent intervals and more gradually, so that the distance between the fly-bars and the bed-plate would correspond with the condition of the stuff? This point could be studied by means of a dynamometer, and I think it stands to reason that a more gradual lowering of the roll would result in the beating of the stuff with a considerably less expenditure of energy than can be accomplished by a sudden spasmodic lowering at three or four intervals during the beating.

In the foregoing trials, the same stuff was used for the Hollander and Taylor beater. In making a comparison between the two kinds of beaters, the kind of stuff must be noted, as this materially affects any comparison made between the two. The Hollander is generally conceded to be an extravagant type of beater, but it compared more favourably with other types when using certain classes of stuff. This point will be made plainer in later chapters.

There is a certain amount of elasticity between the metallic contacts of the two surfaces which must not be lost sight of, due partly to the qualities of the metal *per se*, but more perhaps to the materials employed in packing the beater bars into the rolls. Such may produce more or less of a cushion. Extreme rigidity of contact would punish the fibre more severely than when the beater possesses a certain amount of flexibility.

CHAPTER IV.

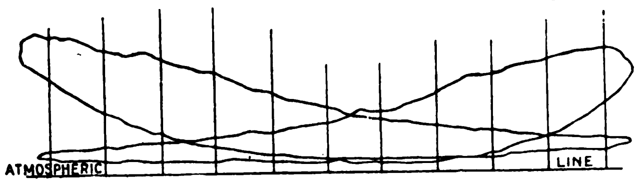
A comparison of two different kinds of beaters by means of indicator diagrams.

WE will now take into consideration the total power consumption by ascertaining the total amount of power consumed by a battery of beaters under average work. We want also to ascertain the amount of power consumed in overcoming the friction of the engine and shafting, as well as the total amount of power consumed by the beaters themselves. The valuable tests placed in my hands by Messrs. Edward Lloyd, Ltd., of Sittingbourne, enable me to give this information in a very complete way. I shall describe this as far as possible in detail, because the *modus operandi* adopted is very thorough, and could be used in other works for similar tests. The steam-engine was made by Messrs. Galloway, of Manchester, and is capable of indicating 400 h.p. The indicator diagrams were taken at Messrs. Lloyd's mills, at Sittingbourne, by the engineer of the Steam Engine and Boiler Insurance Company, of Manchester, and I am informed that Mr. Frank Lloyd was there the whole day himself during the tests.

The following are the diagrams and details :—

HIGH PRESSURE CYLINDER DIAGRAM.—NO. I.

(*Test of actual power required for Engine and Shafting.*)

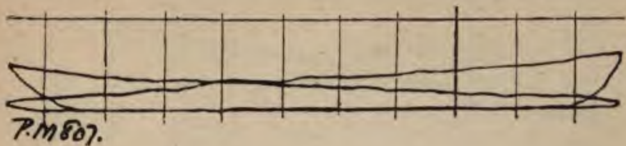


Friction of engine and shafting with all beater belts off, 47·1 h.p.

Mean pressure, 10·5 lbs. Boiler pressure, 75 lbs.

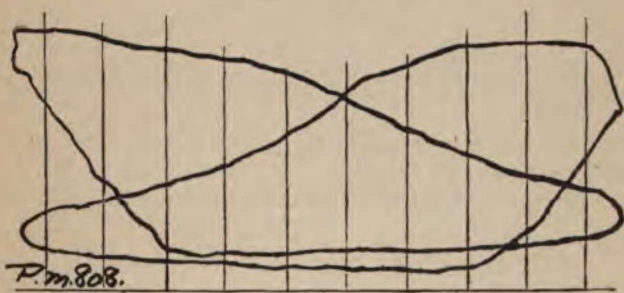
Cylinder, 20 ins. diameter ; stroke, 4 feet ; 59 revolutions.

LOW PRESSURE CYLINDER DIAGRAM.—No. I.



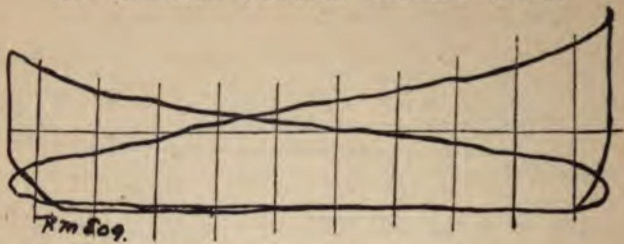
Friction of engine and shafting with all beater belts off, 38·9 h.p.
Mean pressure, 3 lbs.
Boiler pressure, 75 lbs.
Cylinder, 34 ins. diameter ; stroke, 4 feet ; 59 revolutions.
Total indicated h.p., 86.

HIGH PRESSURE CYLINDER DIAGRAM.—No. II.



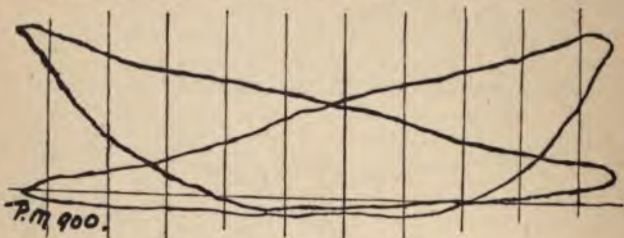
Driving eight Umpherston's beaters, 122·7 h.p.
Mean pressure, 28·7 lbs.
Boiler pressure, 75 lbs.
Cylinder, 20 ins. diameter ; stroke, 4 feet ; 56 revolutions.

LOW PRESSURE CYLINDER DIAGRAM.—No. II.



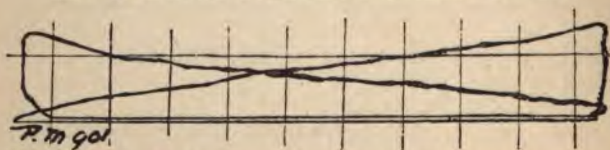
Driving eight Umpherston's beaters, 135·6 h.p.
Mean pressure, 11 lbs. Boiler pressure, 75 lbs.
Cylinder, 34 ins. diameter ; stroke, 4 feet ; 56 revolutions.
Total indicated h.p., 258·3.

HIGH PRESSURE CYLINDER DIAGRAM.—No. III.



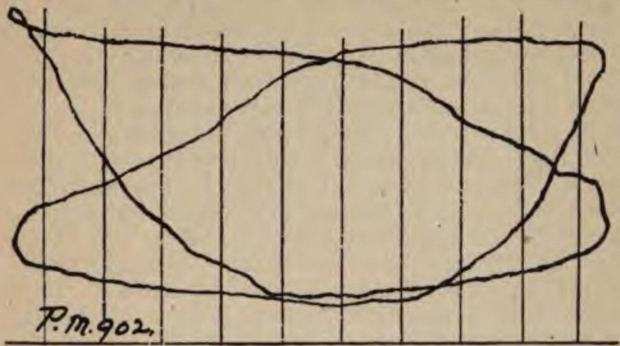
Driving four Taylor patent beaters, 76·3 h.p.
Mean pressure, 17·9 lbs. Boiler pressure, 75 lbs.
Cylinder, 20 ins. diameter ; stroke, 4 feet ; 56 revolutions.

LOW PRESSURE CYLINDER DIAGRAM.—No. III.



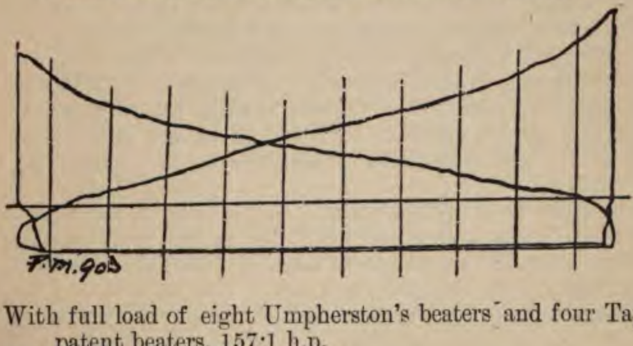
Driving four Taylor patent beaters, 70·2 h.p.
Mean pressure, 5·7 lbs. Boiler pressure, 75 lbs.
Cylinder, 34 ins. diameter ; stroke, 4 feet ; 56 revolutions
Total indicated h.p. to drive eight Umpherston's beaters, 258·3

High Pressure Cylinder Diagram.—No. IV.



With full load of eight Umpherston's beaters and four Taylor patent beaters, 151·7 h.p.
Mean pressure, 36·5 lbs.
Boiler pressure, 75 lbs.
Cylinder, 20 ins. diameter ; stroke, 4 feet ; 54½ revolutions.

Low Pressure Cylinder Diagram.—No. IV.



With full load of eight Umpherston's beaters and four Taylor patent beaters, 157·1 h.p.
Mean pressure, 131·1 lbs.
Boiler pressure, 75 lbs.
Cylinder, 34 ins. diameter ; stroke, 4 feet ; 54½ revolutions.
Total indicated h.p., 308·8.

The method of procedure was to indicate the engine with all the straps off, so as to arrive at the power consumed in overcoming the friction of engine and shafting as shown in Diagram I., p. 50. The steam-engine was then shut down, and the belts were put on the eight Umpherston beaters only. The engine and eight Umpherstons in full work were then indicated, and the difference between Diagrams I. and II. gives the power consumed by eight Umpherstons. When the Umpherston beaters had been tested running about half an hour, the engine was again shut down and the eight belts taken off and the belts of the four Taylor beaters put on, and then tested for about half an hour. The engine was again shut down and the belts of the eight Umpherstons put on, and the four Taylors and eight Umpherstons indicated together in Diagram No. IV. Diagram III. gives us the power consumed when four Taylor engines are substituted in place of eight Umpherston engines. The difference between the power shown by Diagrams I. and III. gives us the power required for four Taylor engines in full work. The final Diagram (IV.) gives the power required to overcome friction of engine and shafting, and to drive eight Umpherstons and four Taylor engines in full work. Mr. Frank Lloyd did not allow any beater to be emptied or filled during that forenoon, and until the test was completed, and no beater-roll was touched—that is, taken off the plate or put harder on the plate.

I give herewith a summary, p. 55, showing the amount of power required to drive eight Umpherstons, and also the power required to drive four Taylor beaters; but it is easily seen that we have an independent way of arriving at the power consumed by the Umpherstons, by making use of Diagrams III. and IV. Also, we have a check upon the Taylors, by making use of Diagrams II. and IV. As these two sets of figures are slightly different, I have thought it fair to represent both sets of figures in the summary, and then to take the mean of both sets for the purpose of final comparison.

In order that readers may, if they desire to, calculate direct from the illustrations the power of the engine from the diagrams as shown (pp. 50 to 53), it is necessary that they should know the scale of the original diagrams. The scale of the original diagrams for the high-pressure cylinders in each case is $\frac{1}{30}$, and for the low-pressure cylinders $\frac{1}{16}$; but as the blocks as shown in the illustrations are not the same size as the original diagrams, it is necessary to make a correction. The correction necessary is *got at as follows:* the original diagrams measure 113 mm., *whereas the blocks* which are produced from them measure

80 mm., the proportion, therefore, is as 80 to 113. In order to arrive at the actual size of the original diagrams from the size in the illustrations, it would be necessary to multiply the measurements taken by 1·41.

SUMMARY OF RESULTS FROM INDICATOR DIAGRAMS I., II., III., AND IV. (pp. 50 to 53).

	Total horsepower absorbed.	Power absorbed by each beater without engine and shafting.	Proportion of power absorbed by steam-engine and shafting for each beater where all engines are going.	Total power absorbed by each beater, inclusive of its due proportion of engine and shafting.
	H.-P.	H.-P.	H.-P.	H.-P.
Friction of steam engine and shafting	86·0	—	—	—
Eight Umpherston beaters from Diagrams I. and II. ...	172·3	21·54	8·38	29·92
Four Taylor beaters from Diagrams I. and III. ...	60·5	15·12	5·88	21·00
Eight Umpherston beaters from Diagrams III. and IV.	162·3	20·29	7·89	28·18
Four Taylor beaters from Diagrams II. and IV. ...	50·5	12·62	4·91	17·53
Total power required for friction of steam-engine, shafting, and to drive eight Umpherstons and four Taylors —Diagram IV.	308·8	—	—	—
Mean of both sets of trials for eight Umpherston beaters—Diagrams I. and II. and III. and IV.	167·3	20·91	8·13	29·05
Mean of both sets of trials for four Taylor beaters—Diagrams II. and IV. and I. and III.	55·5	13·87	5·39	19·26

In the second column of the above summary, we have the power consumed per beater by dividing the figures in the first column by the number of beaters in each case. For the purpose of comparing the relative efficiencies of the two kinds of beaters, this column can be made use of, but for the purpose of determining *the cost of beating*, this column will be misleading, as it does not

include the quota of power consumed by friction of engine and shafting for each beater. To arrive at the latter, we must make use of Diagrams I. and IV.

COMPUTED FROM INDICATOR DIAGRAMS, NOS. I. AND IV.

Power consumed in overcoming friction of steam-engine and shafting	27·9%
Power consumed by twelve beating engines ...	72·1%
TOTAL	100·0%

In round figures we have, then, for every 100 of i.h.-p., 28 h.p. consumed in overcoming friction of engine and shaftings, and the balance 72 h.p. consumed in driving the beaters.

$$72 : 28 :: 18 : 7$$

If, now, we multiply the figures in second column by 7, and divide by 18, we have the proportion of power consumed in overcoming the friction of engine and shafting to be charged to each beater. This is done on the same principle as taxation on assessable value. If, now, we add the figures in columns 2 and 3 together, we have the total horsepower consumption of each beater, inclusive of its due proportion of power consumed by friction of engine and shafting. This last-mentioned figure (as shown in the last column) is the one we should use in calculating the cost of beating.

The percentage of power consumed, as above given, in overcoming the friction of the engine and shafting can only be considered here for the conditions prevailing in Diagram IV. Supposing, for example, this engine was made to drive beaters so as to develop its full power, *i.e.* 400 i.h.-p., and from the same line of shafting. The friction of engine and shafting being a constant quantity (or nearly so) will still remain at 86·0 h.p. But since the total horsepower now developed is 400, the relative figures would be as follows:—

Power consumed in overcoming friction of steam-engine and shafting	21·5%
Power consumed by beaters	78·5%

I merely point this out in order that it may be understood that the last two columns are not absolute figures, but only true for the

conditions that prevailed when Diagram IV. was taken and tested, *i.e.* so long as the total indicated horsepower remains at 308·8.

A few words in regard to the best mode of calculating the cost of horsepower might perhaps be given here. In any well-conducted mill the evaporative efficiency of the boilers is generally known. Of course, this can be ascertained by carrying out elaborate boiler trials; but the best method of all is to keep books showing the exact amount of coal used per week and readings from a meter showing the number of gallons of water evaporated per week in the boilers, with a deduction for the amount of water and consequent loss of heat in the blow-off water, which can also be got at by measuring. We will assume, for the sake of argument, that the evaporative efficiency of the coal is equal to 8 lbs. of water per lb. of coal. This is a good all-round figure. Let us assume that the steam is super-heated to a sufficient extent to prevent any condensation in the steam-pipes, and sufficient to ensure that the steam is only just saturated when it reaches the steam-engine.* Under such conditions, the whole of the water evaporated in the boilers is effective. Now, supposing it is ascertained by indicating the engine that each horsepower necessitates the using of 20 lbs. weight of steam, we should be correct in stating that each indicated horsepower would necessitate the burning of just 2½ lbs. of coal. Knowing the price of the coal delivered at the works, we can easily now arrive at the cost per h.p.-h. (horsepower-hour). In the fourth column of the foregoing summary we have the exact figure for h.p.-h. per beater. Now we can easily calculate the cost for fuel per hour per beater. This is a figure which I venture to think all papermakers should be acquainted with.†

In order now to determine the amount of coal necessary to supply power for beating one ton of stuff, we must of course know the average output per hour of each kind of beater. The following

* Under more modern conditions of, say, 150° "super-heat," and 150° pressure at beaters, this assumption would not be a fair one, but it may be taken to represent the conditions that may be said to prevail in an average paper mill at the time of writing (1904).

† In this and other similar estimates of cost for horsepower no allowance is made for such establishment and other charges as labour, which, properly speaking, form part of cost of power-raising. Such charges vary considerably in different mills, and, in cases where coal is very cheap, may represent a very large proportion of the total cost. I have adopted the usual custom of charging only the main item, namely, the fuel, against the cost for power. Those who wish to apply the figures to their individual mills would have, of course, to make allowance for such items, and correct for the price of fuel.

table gives the necessary particulars, and I think does not require further explanation :—

	UMPHERSTON.	TAYLOR.
Capacity of beater	6 cwt. ...	9 cwt.
Average output per hour	3 „ ...	6 „
H.p.-h. per cwt. of stuff beaten	9·68 ...	3·21
Coal consumed in beating one ton of stuff on assumption that one h.p.-h. = 2½ lbs. of coal ...	484 lbs. ...	161 lbs.

As different classes of stuff consume different amounts of power in beating, it is necessary, of course, for the purpose of comparison, to furnish all round with the same stuff. At the time the indications were taken, Messrs. Lloyd were using the same class of stuff in the Umpherston as in the Taylor beaters.

It is interesting to observe, as a matter of scientific interest, that the dynamometer gives at once, and without calculation, the horsepower or foot-pounds at any period, whereas the indicator diagram only gives it you for the moment the card is taken, and, of course, necessitates considerable calculation.

CHAPTER V.

Power consumed in the breaking, beating, and refining of different materials.

MESSRS. R. AND W. WATSON, of Linwood, Renfrewshire, have supplied me with some useful tests, which not only show the relative amounts of power consumed by the different classes of material under treatment, but they furthermore show how the power is distributed as between breakers, beaters, and refining engines.

In this set of trials the beating and breaking engines are of the ordinary Hollander type. The beaters used in the treatment of new jute threads, new linen threads, and manilla rope have a capacity of 5 cwt. The speed of the beater roll is 163 revolutions per minute; the diameter of the roll is 3 ft., and the width of the face of the roll is 3 ft.; the approximate weight of the roll is 50 cwt.; it is furnished with bars of tempered steel to stand up to the work. These bars are arranged in clumps of three.

The beaters used for the treatment of sulphite wood have a capacity of 7 cwt., and the roll makes 140 revolutions per minute. The diameter of the roll is 4 ft. 3 in., and measures 4 ft. 3 in. on the face. The approximate weight of the roll is 62 cwt.; and the bars are the same, as regards the composition and arrangement, as in the case of the 5-cwt. beaters.

It is important to give this information, because so much depends upon the size of the beater, as well as upon the size and weight of the beater roll and the speed at which it travels, as to the amount of power consumed.

Messrs. R. and W. Watson point out that, besides the shape of the beater and the form of the bars, etc., affecting the results, there are numerous demands made by the users of paper which considerably influence both time and power, such as in the production of a "close" or "cloudy" look through, pliability or stiffness, a long fibre with a soft leathery feel, etc., etc. Of *course, such considerations as these must influence, at any rate in*

a measure, the amount of power consumed in beating; but, for all that, the results given below will, I venture to think, be of great value and throw considerable light upon the question of power consumed in beating.

TABLE I.

Breaking, Beating, and Refining Power Tests on Four Different Classes of Materials.

	New jute threads.	New linen threads.	Manilla rope.	Sulphite wood.
Capacity of beaters ...	5 cwt.	5 cwt.	5 cwt.	7 cwt.
Power absorbed in driving empty beater and motor	4·1 h.p.	4·1 h.p.	4·1 h.p.	4·4 h.p.
Power absorbed in breaking	41 h.p.	55·25 h.p.	25·3 h.p.	—
Time required in breaking	1 h. 45 m.	3 h. 5 m.	2 h. 20 m.	—
Power absorbed in beating	38·75 h.p.	42·6 h.p.	31·6 h.p.	30 h.p.
Time required in beating	1 h. 15 m.	1 h. 50 m.	1 h. 20 m.	2 h. 30 m.
Power absorbed by motor and Marshall running empty	12·6 h.p.	12·6 h.p.	12·6 h.p.	—
Power absorbed in motor and Marshall full ...	34·5 h.p.	63 h.p.	47 h.p.	25·25 h.p.
Time required	20 min.	20 min.	20 min.	30 min.
H.p.-h. per cwt. of stuff from raw to prepared...	26·34	53·83	23·36	12·52
Coal consumed in pulping 1 cwt. from raw to finish @ 3·3 lbs. (slack) per h.p.-h.	86·922	177·639	77·088	41·316

The beaters in this trial were driven by electric motors. There are certain advantages in this for the purpose of making tests, because it becomes a comparatively easy matter to arrive at the electrical horsepower from time to time, without resorting to the work of taking diagrams of the steam-engine and working out the amount of power to be apportioned to each engine.

The results expressed in Table I. in electrical horsepower do not show the losses through transmission, but this part of the subject need not be considered in connection with this section, because it is more in the domain of the electrical engineer. The readings for the power consumption in beating and breaking are *in each case the average* of three independent observations.

The losses in electrical transmission can be easily allowed for; but such losses are not large, and would not affect the relative value of the results here given (in this case $2\frac{1}{2}$ volts drop from beginning to end). Table I. (p. 60). further states the amount of coal (slack) actually consumed per horsepower-hour, from which is calculated the total consumption of fuel for the different materials treated.

Those who use a different class of coal can make due allowance on ascertaining the difference in heat value in comparison with that of slack. Some valuable deductions can be arrived at from this set of tests, because, as far as beating and breaking are concerned, they deal entirely with the Hollander. The Marshall engine is used, in this instance, merely for brushing out the stuff after the beating, very little work being put on the Marshall as compared with the breaker and Hollander. I mention this fact because the proportion of work done by the refining engine varies enormously in different mills. It will be noticed on glancing at Table I. that the power absorbed is given for the beater and motor running empty. This number, viz. 4·1 h.p., applies also to the breaking engine.

The time both for breaking and beating is given, and also the time for passing the contents of each engine through the Marshall refiner. The time is given in the table as the actual time of beating, and does not take into consideration any time for emptying, etc. I venture to think this gives the table the greater value, as any papermaker examining it can make the necessary allowance for himself, provided that he knows the amount of time in his own particular mill during which the beater is running empty in between the beating operations. This, however, is a minor factor, and is hardly worth considering, as, whilst the engine is running empty, there is only a consumption of 4·1 h.p., and, of course, the engine is left empty as short a time as possible. It will be noticed that the power absorbed in running a 7-cwt. Hollander empty is not much greater than that required to run a 5-cwt. Hollander engine empty, and that it is nothing like so great in proportion to the contents of the engine. This, of course, is what one might expect. It might be assumed, therefore, that, other things being equal, it would be more economical to run a 7-cwt. Hollander than a 5-cwt. Hollander. But, for reasons well known to papermakers, the larger Hollander is not suited for many classes of stuff, and consequently, even at the expense of a slightly increased consumption of power per cwt., *the smaller engine* in such cases must be used. If the power

increased *pro rata* with the capacity, on the assumption that a 5-cwt. Hollander consumed 4·1 h.p. when running empty, a 7-cwt. Hollander would consume $\frac{4 \cdot 1 \times 7}{5} = 5 \cdot 7$ h.p., which, by reference to Table I., it will be noticed is 1·3 h.p. in excess of the figure found in practice. It can be seen, therefore, that there is a saving per cwt. (other things being equal) of 1·3 h.p. when changing from a 5-cwt. to a 7-cwt. Hollander, and provided the larger engine would do the work as well in every way, the papermaker would be in pocket by the change. It is interesting to note the amount of power required to run the Marshall engine empty, viz. 12·6 h.p.

TABLE II.

Table showing the Distribution of Power between the Breaking, Beating, and Refining for the Different Materials.

	Breaking h.p.-h. per cwt.	Beating h.p.-h. per cwt.	Refining h.p.-h. per cwt.	Total of Breaking, Beating, and Refining h.p.-h. per cwt.	Breaking.	Beating.	Refining.
					. ct.	p. ct.	p. ct.
New jute threads ...	14·35	9·69	2·30	26·34	54·6	36·6	8·8
New linen threads...	34·03	15·59	4·21	53·83	63·2	29·0	7·8
Manilla rope ...	11·80	8·43	3·13	23·36	50·7	36·2	13·1
Sulphite wood ...	—	10·72	1·80	12·52	—	85·6	14·4

Table II. is calculated from Table I. It deals with the distribution of power between the beating, breaking, and refining. The first three columns give the actual power consumed in horsepower-hours per cwt. by the breaker, beater, and refiner respectively. The fourth column shows the total power consumed for the three processes. From these figures the percentage of power consumed for the breaking, beating, and refining, respectively, are calculated. It is interesting to note that when beating new linen threads the greatest amount of work is consumed in the breaking, the beating only requiring 29 per cent. of the total power consumed. Next follows new jute threads with 54·6 per cent. for the breaking in, and 36·6 per cent. for the beating; refining only requiring, in the case of linen threats, 7·8 per cent., and, in the case of jute threads, 8·8 per cent. of the total power consumed.

With manilla rope the breaking absorbs about one-half of the total power, but the proportion of power required for the refining is considerably greater than in the case of the two foregoing.

With sulphite wood the conditions are different. There is little or no breaking-in to be done, consequently the great bulk of the power is consumed in the beating, leaving 14·4 per cent. for the proportion of power consumed by the refining engine.

Table III.

Table showing how Power is apportioned as between the Friction of Machine and the Beating, Circulating, etc.

	Breaking.		Beating.		Refining.	
	Engine friction.	Breaking and circulating, etc.	Engine friction.	Beating and circulating, etc.	Engine friction.	Refining and circulating, etc.
	p. ct.	p. ct.	p. ct.	p. ct.	p. ct.	p. ct.
New jute threads ...	10·0	90·0	10·8	89·2	36·5	63·5
New linen threads ...	7·4	92·5	9·6	90·4	20·0	80·0
Manilla rope ...	16·0	84·0	13·0	87·0	27·0	73·0
Sulphite wood ...	—	—	14·7	85·3	50·0	50·0

We now come to Table III. This, again, is calculated from Table I., and shows us how the power consumed is apportioned between the "engine friction" * and the beating, circulating, etc. We cannot further dissect this power consumption in these tables. It would be most instructive if we could dissect the items still further, as, for instance, into (*a*) engine friction; (*b*) circulation; (*c*) friction of bars against bed-plate; and (*d*) power consumed in actual beating in rending fibres apart. Of course, the friction of the engine is a constant quantity, or nearly so. If, therefore, the total power consumed during beating is high, the percentage of engine friction on total power consumed is lessened; or, if low,

* Note that the expression "engine friction" is made use of so as to avoid confusion. Engine friction represents the power absorbed whilst engine is running empty with bars off bed-plate, and must not be confused with friction of bars against bed-plate.

the percentage of engine friction on total power consumed is increased.

It will be noticed that in the case of the first three materials in the table, the engine friction during breaking is between 7 per cent. and 16 per cent., according to the material, and is approximately the same in the case of the beating.

With the Marshall it is a different matter : the proportion of power expended on the friction of the engine bears a greater ratio to the total power consumed than with the Hollander.

TABLE IV.

Rate of Output per Hour for Breakers, Beaters, and Refiners, calculated from Table I.

	Breaker.	Beater.	Refiner.
New jute threads	306	448	1680
New linen threads	183	306	1680
Manilla rope	240	421	1680
Sulphite wood	—	313	1568

The foregoing is a table showing the rate of output per hour, calculated from Table I. Of course, this is easily got at from Table I. by dividing the capacity of the engine by the actual time of beating, so as to express the results in pounds per hour. It will be noticed that the output of the 5-cwt. breaker is least with the linen threads and most with the jute threads, the manilla rope occupying a position between the two. With the beater, again, the linen threads give the least output, next comes the manilla rope, and then the jute threads. There is a further thing to be noticed, namely, that the linen threads, besides giving the least output to the breaker and beater, also consumes the greatest amount of power per cwt. in horsepower-hours. This is only what might be expected.

In consequence of the contents of the engine being put through in a period of twenty minutes for each of the first three materials, the output of the refiner is, in each case, 1680 lbs. per hour.

It will be noticed that the rate of output for the 7-cwt. beater, in the case of sulphite wood, is not much more than the rate of output for the linen threads for the beating, but it must not be forgotten that the whole of the work in the case of the sulphite

wood is done in the beater, there being nothing done in the breaker.

The rate of output of the refiner for the sulphite wood is very nearly the same as the rate of the output for the other three materials. I should gather from this that Messrs. R. and W. Watson aim at giving a regular output per hour for each class of material passed through the refiner.

It is well to mention here that the sulphite wood was put in in the form of dry sheets; undoubtedly if the sheets had been put in in a moist condition, *i.e.* containing 50 per cent. of moisture, the power consumed would be diminished; at any rate, this is what we should naturally expect. We know that dry sheets tax an engine if added quickly; it is almost certain, therefore, that dry sheets consume more power than wet ones. I have, however, never even seen this hinted at in any publication. Dry sheets, when added in front of a roll, are drawn under whilst still dry, *i.e.* before the water has time to soak into them. We have found that the tensile strength of dry sheets of long-fibred wood pulp is very high, although when well wetted it will almost fall to pieces. Consequently, considerable power may be expended in drawing the dry fibres apart, which power would be saved when the pulp is added to the beater in a wet condition. Of course, the sheets soon become wetted when added to the beater or breaker, but the roll takes hold of the sheet before the water has had a chance of permeating it.

Table V. shows the total power consumed for each class of material, and, for the purposes of comparison, the second column shows the relative amount of power for each class of material when the lowest power consumption is reduced to 100. It will be noticed that the sulphite wood pulp requires the least power in beating and refining. Manilla rope comes next, requiring 87 per cent. more power per cwt. than sulphite wood. Next comes new jute threads, requiring 131 per cent. more power than sulphite wood; and, finally, we have new linen threads, requiring a much larger expenditure of power, viz. 331 per cent., more than the sulphite wood.

Table V.

The Total Expenditure of Power, from Start to Finish of Beating, and the Ratio of Power consumed in each Class of Material, taking the lowest as 100.

	H.p.-h. per cwt. of stuff beaten.	Relative power consumption when lowest equals 100.
Sulphite wood	12·52	100
Manilla rope	23·36	187
New jute threads	26·34	231
New linen threads	53·83	431

I do not think there are any published results showing comparisons of power consumed in beating different raw materials under known conditions, nor am I aware of any systematic comparison being attempted until Messrs. R. and W. Watson undertook these trials. The above may be regarded as strictly comparable with one another, since they are all done in a Hollander of the same type; the only difference between them being that three of the materials were treated in a Hollander of 5 cwt. capacity, and one of them in a Hollander of 7 cwt. capacity. But this difference, I think, is an insignificant one. As above shown, the only difference between a 5-cwt. and 7-cwt. Hollander that we have any measure of, is a difference of 1·3 h.p.-h. per cwt. of output in favour of the larger engine. It will readily be seen that if a correction were made for this, only a slight difference in the tables would result, and not sufficient to in any way affect our conclusions.

In the case of sulphite wood, the function of the Hollander is chiefly to separate the fibres one from another; but, in addition to this, for some classes of beating the fibres are reduced in length. This would entail a further amount of power consumed. It must not, therefore, be assumed that the amount of power consumed in the beating of sulphite wood is a constant and fixed quantity per cwt.: it must vary somewhat with local requirements and conditions, but, I venture to think, not to any great extent. The same remarks apply to the treatment of all other materials used in the manufacture of paper. There must be a fairly fixed power consumption for reducing raw materials to the state of their *ultimate* fibres; but if the process is to be carried further there

would be a further consumption of power, and this further consumption would depend largely upon the extent to which the reduction is carried.

Elsewhere I have given figures showing the extent to which fibres are often cut when beaten for the manufacture of paper. These can be arrived at by taking careful account of the average length of the ultimate fibre and comparing the same with the average length of fibre taken either from the beaten stuff in the engine or from the paper produced. The results above referred to show that, during beating, the cotton fibre is often cut into thirty pieces; linen into thirty pieces; straw is generally not cut at all; whereas, about one ultimate fibre of esparto in every three is cut. But, as above explained, such figures vary in a measure with local requirements. In this connection, it is interesting to note the figures given by Cross and Bevan, in their book on "Papermaking," showing their determinations of the maximum, minimum, and mean lengths of different fibres as found in papers by well-known makers.

In the ordinary course of events, if very long fibre is required, the beating has to be conducted in such a way as to avoid cutting of the ultimate fibre as much as possible; but this necessitates a longer time in the Hollander, and instead of resulting in a saving of power per cwt. is likely to result in a greater consumption of power through the process being prolonged. Some idea of this subject can be got at by referring the above statement to the dynamometer diagrams given earlier in this work. The above statement may appear to be a contradiction of the statement made previously, but I think I can explain this apparent contradiction.

It is not possible, I believe, in practice, to rapidly reduce any raw material to the state of ultimate fibres without cutting and mutilation. I have shown that, by prolonging the time and letting the roll down more gradually, the horsepower-hours per 100 lbs. of stuff beaten could be very much reduced, but this referred only to the power consumed in beating (which embraces beating proper, friction of rolls against bed-plate, and circulation), and left out of consideration the engine friction. When the engine friction is known, and the consumption of power for beating at different rates of speed, then we can arrive, by simple calculation, at the time of beating which favours the least possible expenditure of fuel. It can be easily seen, therefore, that if the beating is prolonged so as not to cut the ultimate fibre, the total consumption of power may be considerably increased, although, on

the other hand, the power required is, or may be, increased by putting the roll down very hard so as to get the stuff off quickly. Somewhere between these two extremes there should be a period of time for beating which would get the stuff off with the least expenditure of power. This figure would undoubtedly vary, not only with the structural details of the Hollander, but also with the material under treatment.

I have carefully given the number of revolutions and weight of roll, etc., where such information is obtainable, because such things would affect the power consumption. Also details of the arrangement of the bars on rolls are given, as well as diameter of roll, as such details are likely to affect the power consumed by circulation.

The extent to which modifications in the form of the Hollander affect the consumption of power is not known, because no comparative trials have yet been made on this point. I give what details I can because they may prove valuable for the purpose of comparison later on, when other Hollander trials are given.

It must be admitted, I think, that figures such as those given in Table V. have considerable commercial value. Any papermaker should be able to apply this table to his own manufacture. It will, at any rate, give him data to go upon for calculating the relative amount of fuel required for beating these different materials. The tests need, however, to be extended in different directions to render the results of more universal application.

In order that any papermaker may apply these tables to his own manufacture, it would be necessary for him to ascertain what his horsepower costs him in pounds of coal at his own works, and to calculate the figure accordingly. By studying the tables carefully, and forming their own conclusions, readers will profit more than by my attempting to give them a further explanation.

Before proceeding with the publication of any other results, I think it advisable to clear up one or two points. The advantages of electrical driving for the purpose of readily obtaining records of beater tests are quite obvious. It appears to me that many results will eventually be forthcoming from mills where beaters are driven by electrical power.

CHAPTER VI.

A comparison of maximum power consumption of Hollanders of different makes and Taylor beater.

THE following information, supplied by Messrs. Thomas and Green, is of sufficient interest for the purpose of this chapter. At one time indications of their engine were made with the rolls of their various beaters in one instance right up and in another instance right down, the beaters being furnished with stuff in order to ascertain what difference it made to the amount of power absorbed. This difference would represent—

(A) The power absorbed by the friction of the bars against the bed plate.

(B) The power requisite for the actual beating.

As previously explained, there is no means at present of diagnosing these distinct operations; but there is strong evidence to prove that, in ordinary practice, (B) is small in comparison with (A), not only with the Hollander, but with all classes of beaters. Messrs. Thomas and Green point out that they do not absolutely guarantee the reliability of these figures; but the trials were made with great care, and, as far as could be assured, no alteration beyond moving the rolls right up and right down was made during the tests.

The following are the results, as given to me by Messrs. Thomas and Green:—

TABLE VI.

Showing the Power required to drive G. Bertram, Taylor, and Bentley Beaters.

	H.P.
Load on steam-engine with all *three* rolls set clear of plates	206·29
Load on steam-engine with Bertram's roll down *full weight on* plate, Taylor's and Bentley's *clear of plates*	230·74

	H.P.
Load on steam-engine with Taylor's roll down full weight on plates, other two clear of plates	232·67
Load on steam-engine with Bentley's roll down full weight on plates, other two clear of plates	252·92

It is necessary to observe that this test was made with the rolls bearing their full weight on bed plate, and that it is only rarely that such is the case. The figures given are therefore maximum figures, the average being something less.

TABLE VII.

Showing the Difference of Power required by each Beater from above Figures.

				H.P.
Bertram's,	carrying	360	lbs. dry weight paper ...	24·45
Taylor's,	,,	540	,, ,, ,, ...	26·38
Bentley's,	,,	720	,, ,, ,, ...	46·63

The dry weight per beater varies, of course, with the furnish and kind of paper to be produced. The above figures are a fair average estimate, given me by Messrs. Thomas and Green. As it is possible to furnish the Taylor beater thicker than the others, any variation would tend to improve the working capacity of the Taylor as against the other two. The Bertram beater was one of their usual Hollanders, carrying about 360 lbs.; and the Bentley was one of Bentley and Jackson's usual Hollanders, carrying about 720 lbs. As far as can be ascertained, the engines, when running with rolls first up and then down, were fully furnished with stuff. The ordinary Hollander tests took from 3¼ to 4½ hours to beat off. The Taylor 3¼ to 4¼ hours (or 71 minutes and 46½ minutes per 100 lbs. stuff, respectively).

In answer to an inquiry, Messrs. Thomas and Green inform me that, as far as can be remembered, no tests have been made of the Taylor beater with the circulator off, and as pulp would not circulate without it, throwing off of the circulator would not only diminish the power to the extent of the power absorbed by the circulator, but it would be equivalent to the roll running free of the stuff, since, of course, the circulation of the stuff would stop.

It will be remembered that in the analysis of results given earlier there is a note inserted against one of the readings, "Agitator stopped" (see p. 46), and it will furthermore be noticed by comparison of the results there shown, that taking the agitator

off has not materially reduced the power consumption, indicating that the "agitator" consumes very little power. The "agitator" here referred to is the archimedean screw, which was originally placed in the vat for agitating the stuff, so as to keep it in motion, and to prevent lodgment, but this agitator or screw, I am informed, in no way assisted the circulation, as the fan of the present Taylor engine does. This archimedean screw took very little power, and travelled very slowly. In the more modern engines this has been entirely dispensed with.

I have in this chapter no data to go upon showing the amount of power required by the circulation alone for a given stuff and for a beater of given capacity.

The results above given, a summary and analysis of which appear later, show primarily a comparison between the different beaters when the maximum power is expended—*i.e.* when the beater rolls are fully down; they cannot be regarded as showing the power consumption per hundredweight of pulp treated. What they do show, however, in addition to the above, is what the maximum power consumption would be per hundredweight of pulp, provided the rolls were fully down for the whole period of the beating, which, however, of course, is never the case. My object in expressing the figures in Table VIII. in this form is to arrive at subsequent comparisons, from which useful deductions can be arrived at. It is obvious that merely expressing the additional amount of power consumed per beater when the roll is down full weight, as compared with when the roll is right up, would have very little value unless it could be regarded in relation to the capacity of the beater and its output.

TABLE VIII.

Summary showing the MAXIMUM *Power consumed if Roll put right down on Bed Plate for Full Period of Beating, the Figures being for beating and friction of Fly-bars against Bed Plate only.*

	Bertram's Hollander.	Bentley's Hollander.	Taylor's beater.
Capacity of beater	360 lbs.	720 lbs.	540 lbs.
Maximum power for each beater ...	24·45 h.p.	46·63 h.p.	26·38 h.p.
Average time of beating	3·87 hours	3·87 hours	3·75 hours
Maximum h.p.-h. per beater ...	94·62	180·45	98·92
Maximum h.p.-h. per cwt. of stuff	31·54	30·15	20·50

It will be noticed in the above that the maximum power required by Bertram's Hollander is far less than Bentley's Hollander; but, on the other hand, Bentley's Hollander has double the capacity of Bertram's. It must also be observed that the average time of beating is the same for the two Hollanders. When the roll, from being right up, is put hard down, there is not much difference between the horsepower-hours per hundredweight of stuff under treatment. In fact, there is nothing to choose between the two makes of Hollanders. The results show a saving in power of about five per cent. in favour of the 720-lb. Hollander, as against the 360-lb. Hollander. This is only what might be expected, as it is generally admitted, I think, that a larger engine, other things being equal, shows always a slight economy in power consumption. In the particular instance under our notice, this is certainly so, as far as the power consumption for actual beating and friction against bed plate is concerned. It is interesting to compare this with the results obtained where we had under consideration the difference in power required to drive a 5-cwt. and a 7-cwt. Hollander running empty. It will be remembered that in this instance there was a saving in power per hundredweight of stuff equal to 1·3 h.-p. by the use of the larger engine. The results so far obtained go, therefore, to show that in all respects a larger Hollander is more economical, in comparison with the output it gives, than a smaller one.

It is instructive to compare the above Table VIII. with the summaries given earlier in the work, dealing with the *average* power throughout the whole of the beating, giving the actual expenditure of energy per horsepower-hour for the stuff under treatment. Our figures here are only maximum figures.

Table IX.

Showing the Maximum Power Consumption with Rolls right down, and Average Power Consumption for Beating and Circulation. Figures derived from above Summary and a previous Summary.

	Hollander.	Taylor.
Maximum per beater ...	24·45 h.p.	26·38 h.p.
Average per beater ...	16·74 h.p.	16·60 h.p.
Percentage of *average* on maximum	68·5 per cent.	62·9 per cent.

The foregoing table gives a useful comparison, for it deals

average power expended per beater for circulating and comparison with the *maximum* power expended when put hard down. It will be noticed above that the of average on maximum for Hollander and Taylor ly speaking, approximately the same, and the average ughout the beating may be taken as two-thirds the under the conditions of these trials. We may conclude that if all the beaters were furnished at one time (a of course, which never obtains in practice), at the close ng, when all the rolls were fully down, the consumption for beating and circulating would be half as much again age power consumed for same in the ordinary course of Hence the advisability in a battery of beaters of having in the various beaters in different stages of treatment, ensure a uniform load for the engine. In Table VIII., Bertram Hollanders and Taylor beaters have a capacity and 540 lbs. respectively. It will be noticed that, in ice, they bear the same ratio to each other; in other Taylor beater is furnished with 50 per cent. more the Hollander. Both trials were conducted in Messrs. and Green's mill, and presumably in the same engines. think that the comparison I have made in Table IX. one.

TABLE X.

Ratios of Maximum Powers consumed per Cwt. of for Beating, Circulation, and Friction of Bars against Plate.

	H.P.-H. per cwt.	Ratio when lowest = 100.
m's Hollander	31·54	153·8
's Hollander	30·15	147·1
's patent beater	20·50	100

ove table merely gives the maximum power consumed stuff for the three beaters, for beating and friction of bed-plate, and presumably for circulation also, as the annot be conducted, in the case of the Taylor, without stuff in circulation. In the case of the Hollander, circulation is somewhat more complex. When n, the circulation is at its maximum; but as the beater-roll recede from the bars on the bed-plate, of the rolls being raised, the bucket-lifting action

(as described on p. 9) becomes lessened through the stuff slipping back between the spaces. When the roll is right up, the circulation is largely dependent on centrifugal force, and less upon the bucket-lifting action. The consequence is that the circulation slows down. As a result of this, the raising of the roll of the bed-plate not only results in a less consumption of power through the stoppage of the beating, but also through the cessation of the circulation. A comparison, therefore, of results between the Hollander and Taylor beaters is not strictly analogous, the Taylor beater maintaining its circulation to the fullest extent, whilst the circulation in the Hollander slows down. If the circulation in both could be maintained whilst the rolls were raised, the figures should show rather more in favour of the Taylor than above shown. As it is, the maximum power consumed for beating, per cwt. of stuff beaten, friction of bars against bed-plate, and circulation, is about 50 per cent. greater in the case of the Hollander as compared with that of the Taylor, under the conditions in which the trials were conducted at Messrs. Thomas and Green's works.

CHAPTER VII.

Dealing with the circulation and agitation in a Hollander—The changes in rate of circulation at different stages of beating, and the power uselessly expended.

As regards the use of new materials for bars of rolls and bed-plate, the use of a stone bed-plate has been the habit in some mills for many years, more particularly, perhaps, for the beating of rope. The more extended use of stone, either for the roll or as bars to be furnished to the rolls, is of recent date. The basalt lava stone is the one most commonly in vogue.

If one makes an examination of the surface of the stone, such as is used for this roll, and compares this surface with that of the "bronze" or steel commonly used in practice for beater-rolls, it will not be difficult to realize why stone may have advantages over metal.

The amount of force exerted when a stone roll is brought into immediate contact with a stone bed-plate is not necessarily wasted, as in the case of metal. With stone, it was once thought that a far larger proportion of the force expended is utilized in drawing asunder the ultimate fibres—*i.e.* in the beating proper—consequently that there would be a much less loss through friction by contact with the bars against the bed-plate; hence the supposed economy in substituting the stone for metal. Whether this is borne out by actual practical results can only be ascertained by conducting trials somewhat on the lines of those already cited.

There is one other very important point in connection with this matter. The factor of time is more or less eliminated, or perhaps it would be more correct to say that time is a smaller factor, in producing what is known as wet stuff. It is generally supposed that with the Hollander, or any other form of beater, certain time is necessary for beating very long and wet stuff—perhaps six, or eight, or ten hours, according to requirements. With a stone roll, this extended time is no longer necessary, as

the "hydration," which is more or less a chemical action aided by mechanical means, is brought about in much less time.

It remains yet to be proved whether a stone roll can be used with advantage for all classes of raw material: so far its general adoption has not found universal favour. Its action appears to be that of drawing out and separating the ultimate fibres, and, if need be, causing them to work wet, producing a very transparent paper. But it remains to be proved whether the stone roll would cut the fibres to shorter lengths. If it cannot be made to accomplish this, perhaps a sharp treatment in another form of beater or refining engine would be all that is necessary to shorten the length of the fibre after, or before, it has been treated with the stone roll. Beaters are now constructed with two rolls, one being provided with stone bars and the other with metal bars, so as to give the advantages of both systems.

It is generally conceded, I presume, as the result of everyday practice, that the fly-bars of a roll should travel past the bed plate at a given rate of speed, sometimes called the surface speed. The late Mr. Bryan Donkin aptly termed it "circumferential speed," and I think no better definition could be given. How is it that circumferential speed approximating to 2000 ft. per minute has been found the most suitable for beating in the Hollander? I presume it has a great deal to do with the question of centrifugal force at this speed aiding the circulation to the utmost; or it may be due to the bucket-lifting capacity of the spaces between the clumps promoting a circulation round the Hollander consistent with its natural rate of flow. At a higher rate of speed much of the stuff is thrown right over, creating a barrier consisting of a wall of falling stuff right in front of the roll. This, of course, in addition to retarding the travel of the stuff, entails a waste of power through unnecessary agitation. It would be interesting to test the speed of a Hollander beater roll in relation to the amount of power consumed, as well as in relation to the rate of beating and circulation. This could be accomplished by having an arrangement whereby the revolution of the roll could be varied at will, and at the same time having a dynamometer attachment; or the same could be accomplished perhaps with less trouble by having the beater electrically driven.

It must be noticed that the Marshall engine requires about three times the amount of power to run it empty as compared with that required by a 5- or 7-cwt. Hollander. On the other hand, the output of the Marshall engine, under the conditions of these trials, was four or five times that of the beater. It follows

that the amount of power consumed in overcoming the friction of the refiner itself, in comparison with its output, is less than that of the beater. In consequence, however, of a Marshall engine requiring about 12 h.p. when running empty, the output should be made as great as possible consistent with obtaining the stuff in the proper condition. It is important, also, to ensure that the Marshall is not allowed to remain running empty more than is absolutely necessary, from the fact that the Marshall running empty is wasting as much power as three ordinary empty Hollanders of 5- to 7-cwt. capacity.

Comparison between the two sizes of Hollanders and the Taylor beaters, with roll up and with roll down (previously cited), enables us to arrive at some idea of the amount of power required for beating and circulation together, but throws no light on the question of circulation *per se* in either case. We are at present without information on the subject of the amount of power absorbed by the friction of the fly-bars against the bed plate. It is difficult to see how information on this subject can be obtained under present conditions; but, in proportion as our methods of beating are improved by the use of materials for fly-bars which give the maximum beating effect, and by lowering the beater roll gradually and carefully, the amount of power wasted by friction of fly-bars against bed plate will be diminished. It is idle to speculate in the light of our present knowledge of the extent to which its reduction might be carried; but, undoubtedly, there is room for very great improvement in this direction; this I have reason to infer from examination of varions dynamometer diagrams.

We will next consider an aspect which will throw considerable light on the power required for circulating and agitating the stuff in a Hollander.

I am indebted for the following results to a friend who has taken great pains in their preparation, but has asked me not to publish his name. It is impossible, therefore, for me to make any public acknowledgment to him and to his firm, who also desire that their name should not be made public, and who have so generously contributed their results to this publication.

The experiments were conducted on the following lines :—

1st. Indications were made of the engine and shafting only.

2nd. An indication of the engine was made with the engine, shafting, and five beater-rolls, running with beaters empty.

3rd. The beaters were filled with water, and another card taken *whilst the rolls* were off the plate.

4th. A further card was taken with the engine, shafting, and five beaters working on average beaten stuff, but with the roll off the plate.

5th. A set of cards were taken with the rolls down, as in the ordinary daily routine of work in the mill.

The furnish in the mill at the time the diagrams were taken was 60 per cent. of rag and 40 per cent. of soda wood. Three engines were furnished with rag, and two engines with the soda wood pulp.

The following details in regard to the beater should be noted:—The diameter of the beater roll is 5 ft. 7 ins. to the outside edges of the bars. The speed of the beater roll shaft is 170 revolutions per minute, which gives a speed at the periphery of the roll of 1912 ft. per minute.

The beaters are of the ordinary Hollander type, carrying without loading about 500 lbs. of stuff. No doubt they were put up for 4-cwt. beaters.

I am informed that the Insurance Company carried out a series of experiments with the same engine at a speed of 68 revolutions, and the power developed by the engines was 191·4 i.h.p. This indication would have been of great value in confirmation of later tests had it not been for the fact that at the time the Insurance Company took their cards a pump and hoist were driven from the shaft. The steam consumption was stated by the Insurance Company to work out at 23·35 lbs. per i.h.p.

It will be noticed that the total indicated horsepower during the Insurance Company's tests was 191·4, as against 185·6, a difference of 5·8 h.p., which, no doubt, is accounted for by the extra power required for the pump and hoist. The manager, when he made his tests, purposely had the pump and hoist disconnected, so as to eliminate any outside sources of error.

In order to arrive at the mean output on which to base my figures for the consumption of power per cwt. of stuff, I have taken the mean of figures sent me, in which is given the average output of two classes of paper. In the one case for 40–44 lbs. Double Demy, the average output is 7500 lbs. in twelve hours.

On writings of 18–23 lbs. Cream-Laid Large Post, the average output is 5750 lbs. in the same time.

The mean of these two figures is 6625 lbs. per twelve hours, making an average output of 552 lbs. per hour.

Table XI.

Engine Indications.

	I.H.P. per engine.	I.H.P. per beater.
1	22·9 ...	3·81
2	36·3 ...	7·26
3	74·8 ...	14·96
4	107·8 ...	21·56
5	185·6 ...	37·12

The figures 1, 2, 3, 4 and 5 refer to conditions as described above.

Table XII. is arrived at from Table XI.

Table XII.

Analysis of Power absorbed per cwt. of stuff, based on an Average Output of 500 lbs. per hour.

	H.P.-H.
For friction of steam-engine and shafting ...	4·663
For friction of empty beater	2·727
For circulation and agitation of stuff	14·560
For beating proper and friction of bars against bed plate	15·843
	37·793

The horsepower-hours to be debited per cwt. of stuff beaten, for friction of steam-engine and shafting, is arrived at from Table XI. as follows :—

$$\frac{22{\cdot}9 \times 112}{550} = 4{\cdot}661 \text{ h.p.-h.}$$

And for the friction of empty beaters as follows :—

$$\frac{(36{\cdot}3 - 22{\cdot}9) \times 112}{550} = 2{\cdot}728 \text{ h.p.-h.}$$

For circulation and agitation as follows :—

$$\frac{(107{\cdot}8 - 36{\cdot}3) \times 112}{550} = 14{\cdot}560 \text{ h.p.-h.}$$

For beating and friction of bars against bed plate as follows :—

$$\frac{(185{\cdot}6 - 107{\cdot}8) \times 112}{550} = 15{\cdot}843 \text{ h.p.-h.}$$

For the total from start to finish as follows :—

$$\frac{185{\cdot}6 \times 112}{550} = 37{\cdot}795 \text{ h.p.-h.}$$

Table XIII. is calculated from Table XII. into percentages, so as to show how the different factors are apportioned.

Table XIII.

Table showing Successive Stages of Total Power absorbed, based on previous Table.

	H.P.-H. per cwt. of stuff beaten.
For friction of steam-engine and shafting ...	4·660
For friction of steam-engine, shafting, and empty beater	7·387
For friction of steam engine, shafting, beater and circulation	21·947
For total power absorbed, consisting of friction of steam-engine, shafting and beater, and power absorbed in circulation as well as for beating power and friction of bars against bed plate	37·790

Table XIV.

Analysis of Power absorbed, expressed in Percentages on Total Power Consumption.

	Per cent.
Friction of steam-engine and shafting	10·3
Friction of empty beater	9·3
Circulation and agitation of stuff	38·5
Beating proper and friction of bars against bed plate	41·9
	100·0

When the cost of the horsepower-hours is known for any particular mill—(*a*) the cost for friction of engine and shafting,

(*b*) for friction of empty beater, (*c*) for the circulation of the stuff and for the beating proper, including the friction of bars against the bed-plate, can be easily arrived at by a simple calculation, provided that the Hollander is similar in type to the above, and worked with similar materials.

Table XIV. gives us figures which we have not been able to obtain from previous tests. It distinguishes between the circulation and the beating. It will be noticed that the power required for circulating and agitating the stuff in the beater is 38·5 per cent., a much larger item of cost than for friction of the empty beater, which is 9·3 per cent. of total. It will furthermore be noticed that the beating proper, together with the friction of bars against the bed-plate, absorbs 41·9 per cent. of the total power, and only slightly more than the power absorbed by circulation and agitation of the stuff.

I shall endeavour to show hereafter how to distinguish between the circulation and the agitation of the stuff by a few simple observations and a simple calculation, which can be done in almost any mill. But in order to make these figures of practical value, it would be far more useful to have the full data as contained in Table XIII. for the purposes of comparison.

There is little doubt in my mind, from the few rough observations I have already made, that the power required for the actual circulation of the stuff round the Hollander, which can be gauged by the power necessary to raise the stuff from the height of the bed-plate to the level of the back fall, is very small in comparison to the amount of power absorbed in agitating and churning the stuff about.

On referring to an earlier part of this work, it will be noticed that the amount of power absorbed in overcoming the friction of the engine and shafting was very much greater than in the case which we have now under consideration. In the former case, the amount of power required to overcome the friction of the engine and shafting was 21·5 per cent. of the whole, whereas in this case it is only 10·3 per cent. of the whole.

As above stated, it is possible to arrive at the amount of power consumed in the actual circulation of the stuff in the Hollander by a very simple process. It can be done in the following manner —one which I have roughly tried.

To perform properly it is necessary to stand over the beater and note the time the stuff takes to travel, say, exactly half round the beater, or to make one complete revolution. Of course, as we all know, the stuff makes a revolution much faster against the

mid-feather than it does against the outside edge; this is chiefly due to the fact that the distance it has to traverse is about double at the outside to what it is against the mid-feather. An examination of a plan of a Hollander will make this evident. If the stuff travels at a uniform rate throughout its width, and assuming that the distance on the inside travel is one-half of what it is on the outside, the stuff on the inside would travel round twice to every once on the outside, and the stuff in the centre would travel at an intermediate pace. This perhaps is a disadvantage from the point of view of uniform beating.

To time its travel, it is a very good plan to put some mark on the surface of the stuff. I would suggest the following plan for obtaining accurate information on the subject of circulation :— Take the line of travel (*a*) at the outside, (*b*) at the centre, and (*c*) against the mid-feather. This should be done fifteen minutes after filling in, again when the stuff is half beaten, and finally a few minutes before the stuff is discharged from the beater. From this calculate the mean rate of travel.

In order to ascertain whether the stuff on the surface is travelling at the same rate as the stuff near the bottom of the beater, a stick should be inserted vertically in the *thick* stuff to within a few inches of the bottom, and left to travel round. It should be noted whether the stick has a tendency to incline either towards the flow of the stuff or in the opposite direction. The extent to which the stick inclines would indicate the difference in the flow between the surface and the body of the stuff. If there is little or no difference, it is unnecessary to make allowance for same in the circulation; but if the inclination is very marked, the angle should be noted for a given travel round the beater, and due allowance made. A very good idea can be got of the time the flow is passing round the beater when the colour is added; but it is important that observations should be made not only at the close of the beating, but also at the commencement, and when the beating is half accomplished.

The next observation is to note the difference between the height of the bed-plate and the mean height of the stuff as it passes over the back-fall. This should be done at the same time as the rate of travel is noted. Finally, it is necessary, at the close of the beating, to take a bottle of the stuff (care being taken that an average sample is removed); in this, the amount of dry weight of stuff is determined by drying down and burning. The dry weight, less ash, will give the fibrous matter. We must also note the dry weight of furnish of the beater. Supposing, for the sake

of argument, the beater was known to contain 4 cwt. of dry fibrous stuff, in addition to mineral matter, and a sample of beaten stuff, on drying down, was found to contain 6 per cent. of total dry weight, 1 per cent. of which was mineral matter. This would show that there was 5 per cent. of fibrous matter; in other words, that the proportion of fibrous matter to the total weight in the beater is as 1 is to 20. If, then, the beater is known to be furnished with 4 cwt. of dry stuff, the total weight in the beater would be 80 cwt.

By arriving at the mean time that the stuff takes to make a complete revolution in the beater, as explained above, and knowing the total capacity of the beater by performing the above experiment, and also knowing the mean height between the bed plate and the stuff flowing over the back-fall, we could determine, by a very simple calculation, the number of foot-pounds per minute exerted by the beater-roll in raising the stuff from the level of the bed-plate to that of the back-fall, from which we could calculate the horsepower used up in actual circulation.

This figure, divided by 33,000, would give us the horsepower per minute, and, multiplied by sixty, would give us the horsepower per hour. Taking into consideration the output of the beater, we can arrive at the horsepower per hour consumed in circulation per hundredweight of stuff beaten.

This plan of procedure sounds somewhat complicated, but it is easier, perhaps, to perform than to describe, and is by no means difficult for anybody to perform when the general principles are grasped. It can be easily seen that the actual amount of power required to circulate a Hollander is equal to the foot-pounds required to lift the stuff over the back-fall.

In the foregoing results (pp. 78 to 80) it is impossible to distinguish between the power required for beating the wood pulp and beating the rag, as the indications are done on the engine with all the beaters running. It took about three and a half hours to bring the wood pulp to the necessary degree of fineness, and about four and a-half hours for the rag pulp. But I consider the chief point about these trials is the figure for the proportion of power consumed for circulation and agitation.

The amount of power consumed when the five beater rolls were running off the plate in water was 38·5 h.p., and when running in average beaten stuff was 71·5.

It will be noticed, therefore, that the consumption of power in beaten stuff is 85·7 per cent. greater than when the rolls are running in water alone. This does not agree with the result

obtained by the Continental authority who was cited in a previous chapter, although it does not necessarily run counter to it. What the Continental authority stated was, that the roll running in thick beaten stuff absorbed less power than a roll running in water only; but it is possible that the thickness of beaten stuff was so great as to draw under the roll very slowly at the commencement of the beating, and it seems to me very probable that the beater when first furnished, if the stuff is moving very slowly indeed, would, if the roll was off the plate, consume less power than if the beater were full of water, although when the stuff gets further beaten the power consumption for circulation is increased, in consequence partly of the increased rate of travel and partly to the stuff finding a higher level in front of the roll.

I have, in all cases under the head of "Circulation," signified the power required to merely cause the stuff to travel round the beater, and, under the head of "Agitation," all the power expended in the way of beating the air into the stuff, churning it about, and causing it to pass completely over the roll and splash against the bed plate, etc.

The following somewhat elaborate mode of arriving at the actual amount of energy required for the circulation proper, I give in detail. It is, I believe, the first time this item has been diagnosed and isolated from the rest of the factors of beating.

It was, first of all, necessary to arrive at the distance round the beater near the outside L (see Fig. 11), in the centre N, and close to the mid-feather P. In order to do this, laths were fixed radially from the mid-feather to the outside, with three nails in the three positions above-mentioned on each lath. By taking cords along the lines of these nails and under the roll, the distance traversed by the stuff at each of these positions was measured.

The following method was adopted for taking the time for the travel of the stuff along the different points: A little blue tinting was put in, making a spot of colouring on the white pulp, about 2 ins. in diameter, at the three points L, N, and P. The time was taken at different periods of the beating required for these spots to make a complete revolution. It was quite easy to distinguish these spots as they passed through the roll and emerged at the three points, P, N, L. The distance from E to F represents length of one complete revolution close to mid-feather; C to D, distance at centre; and A to B, distance at outside. The mean distance of one revolution is based upon the mean of these three measurements.

The percentage of loading and the weight per ream have a

good deal to do with the travel of the stuff; in fact, the consistency and composition of the stuff affect the question of circulation considerably. It is considered expedient, therefore, to give a complete description of the furnish, which was for Double Crown, 24 lbs.

It will be seen on looking at Fig. 11 that the width on the side by the roll between mid-feather and edge is 3 ft. 9 ins.; that on the other side is 3 ft. 3 ins. The beater roll, without the bars, has a diameter of 3 ft. 3 ins., and width, 3 ft. 6 ins. Consequently the bars or clumps of bars protrude to the extent of $1\frac{1}{2}$ ins. The distance between the end of the mid-feather and the end of the

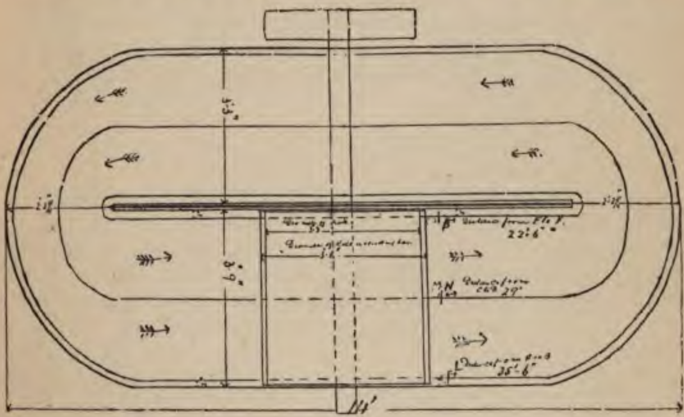


FIG. 11.

beater is 2 ft. $2\frac{5}{8}$ ins. The depth of the beater on the shallow end is 2 ft., and on the deep end 2 ft. 6 ins.

The rough sketch of elevation, Fig. 12, is instructive as showing the gradient of the stuff in its travel from the point L, higher limit, to the point D, lower limit. As the stuff leaves the roll its level is equal to that of the top of the mid-feather, and is 13 ins. above that of the top of the back-fall. The line consisting of long dashes shows the gradient of the stuff, and that consisting of short dashes the mid-feather.

It will be noticed that the surface of stuff gradually falls, until on its return it just brushes the spindle. The fall appears to be in a greater ratio from the point C to the point D, where it touches the roll again.

The level of the bed-plate is 6 ins. above that of the bed of trough of the beater.

The depth of the stuff as it touches the roll at D is 14 ins., or an inch more than the depth of stuff as it rises over the back-fall. The depth of the stuff at no point is greater than about 2 ft. 5 ins., taking a vertical line from the surface of stuff to the bottom. The greatest depth is just where the back-fall meets the bottom of the beater—*i.e.* where the mid-feather ends on right hand.

In consequence of the vertical sectional area of the stuff being reduced at certain points, the rate of flow at all points is not constant. Thus, at the points P, L, M the rate of flow is at its maximum, in consequence of the sectional area of the stream being the least. At D, where the depth is 14 ins., as compared with 13 ins. at the points above-mentioned, the rate of flow is only

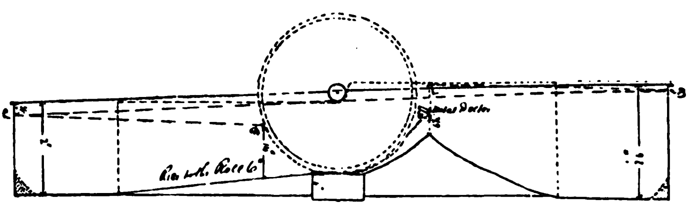


FIG. 12.

slightly less; whereas, of course, the rate of travel where the stuff is reduced to a fine film between the roll and the bed-plate is approximately equal to the circumferential speed of the roll-bars, which can easily be calculated for any roll when the revolutions per minute and size of roll is known.

At or near where the mid-feather ends on the back-fall side—*i.e.* at the point where the vertical depth, and consequently the sectional area, of the stuff is greatest, the rate of flow is the lowest; the reason being that the total volume per minute passing any given spot at any given period of time during the beating is a regular quantity. It follows, then, that the rate of flow in feet per minute is inversely proportional to the sectional area. And it follows, therefore, that when once the rate of flow in feet per minute at any given point in its travel round the beater is known, the rate of speed at all other points can be readily calculated. Figures exemplifying this statement are given later in this chapter.

For the purposes of the experiment about to be related, an

engine of bleached sulphite wood was taken and filled in to a fair consistency. The total weight of the pulp in the beater was 590 lbs. As this pulp on sampling was found to contain thirteen per cent. of moisture, the actual amount of air-dry pulp would be—

$$\frac{590 \times (100-13) \times 100}{100 \times 90} = 570 \text{ lbs.}$$

The furnish in the beater was as follows :—

Bleached sulphite wood (air dry weight)	570 lbs.	
Sulphate of alumina	36 „	
9 galls. of size, representing in dry rosin	8 „	
Starch	25 „	
China clay	60 „	
Representing—		or, say
Combustible materials	603 „	600 lbs.
Non-combustible	96 „	100 „
	699 „	

After the experiment was completed, a sample of stuff weighing 1000 grains was carefully taken, and the residue dried down, and was found to weigh 78 grains. Fifty grains of this was ignited and found to weigh 6 grains, showing 12 per cent. of ash on the dry weight. This gives us the following percentages :—

Residue on evaporation, reckoned on original weight of stuff, is therefore—

	Per cent.
Combustible (fibre and starch)	6·9
Incombustible (minerals and alum)	0·9
Total	7·8

Of combustible furnish, about 4 per cent. is starch ; therefore we must deduct $\frac{6{\cdot}9 \times 4}{100} = 0{\cdot}3$ per cent. from the 6·9 per cent., leaving 6·6 per cent. as the proportion of fibre on the total weight of beaten stuff.

As we have 570 lbs. of air-dry wood pulp in the furnish, the total weight of the stuff in the beater, including water, etc., equals—

$$\frac{570 \times 100}{6{\cdot}6} = 8637 \text{ lbs.}$$

The time that the stuff was in the beater was actually $5\frac{1}{2}$ hours, but only 5 hours of this was actually taken up in the process of beating.

The time of travel was noted (1) $\frac{1}{2}$ hour after filling ;
(2) 3 hours after filling ;
(3) 5 hours after filling.

Table XV.

Table showing the Distance the stuff has to traverse for revolution round Hollander at the three points, and also Time which the stuff situated at these points takes to make a complete revolution at the different periods of the beating.

Points indicated on sketch (Fig. 11).	Distance round.	Different Stages of Beating. At start. (1)	Half-time. (2)	At finish. (3)
L	Outside, 35′ 6″ ...	12 min.	11 min.	10 min.
N	Middle, 29′ 0″ ...	8 „	7 „	12 „
P	Mid-feather, 22′ 6″	7·5 „	6·5 „	6 „
	Mean, 29′ 0″ ...	9·2 „	8·2 „	7·5 „

Mean of all 1, 2, and 3 = 8·3 mins. for once round beater.

Column (1) shows the time required for stuff to make one complete revolution of beater, half-hour after filling in, *i.e.* when beating commenced. Column (2) the same 3 hours after filling, *i.e.* at half-time. Column (3) the same 5 hours after filling in, or when beating was just on finished.

It will be noticed, on referring to the above table, that column (2) is practically the mean of columns (1) and (3). From this it might be inferred that a gradual and regular increase in the rate of flow is taking place as the stuff gets more beaten.

Table XVI.

Table showing the Rate of Travel of the stuff in feet per minute at the three different periods of beating, and at the three different positions indicated.

Fig. 11, at points		(1) Beginning.	(2) Half-beaten.	(3) Finish.
L	Outside	2·96′	3·22′	3·55′
N	Middle	3·63′	4·14′	4·46′
P	Inside (mid-feather)	3·01′	4·46′	3·75′
	Mean	3·20′	3·16′	3·92′

Mean of all = 3·58 ft. per minute.

The above table is calculated from Table XV. by taking the distance round the beater, and the time taken to make a complete revolution of the beater. The figures in columns (1), (2), and (3) show the actual rate of flow in feet per minute, from which some useful information can be derived.

Before considering the comparative rates of flow at the outside, middle, and inside, as also the increment which takes place in the rate of all three as the beating advances, let us examine into the value of the mean figure derived from Table XVI. This figure is 3·58 ft. per minute, and gives us the mean rate of flow, not only for the whole time of beating, but also for all parts of the beater. At the least depth the rate of flow would be greater than this, and at greatest depth it would be less than this figure. In the instance of these trials the mean depth of stuff is 2 ft., which, it will be noticed, is reached just as the stuff passes under spindle of roll. We should have the following rates of flow in the centre of the stuff :—

	Flow of stuff in feet per minute.	Ratio when mean = 100.
At maximum depth of 30 ins. ...	2·86	80
At mean depth of 24 ins.	3·58	100
At minimum depth of 13 ins. ...	6·61	185

For any rate of flow of the stuff in beater and any period of the beating, the relative rates of speed for the maximum depth (*i.e.* at back-fall), the mean depth (*i.e.* where the stuff passes under spindle), and minimum depth (*i.e.* where the mid-feather ends at back-fall side) would be maintained. In other words, they would bear the following relation to one another for all speeds: 80 : 100 : 185. It must not be lost sight of that the maximum speed is at the minimum depth, and the minimum speed at the maximum depth. In fact, the flow of stuff round a Hollander is found to obey the same laws as the flow of water along the bed of a river. The bed of a river, it must be assumed, has a steep incline during the first part of its course, then a considerable portion of bed without incline, and towards the end the bed shelves up, in the form of an inclined plane, to a bay, over which it falls. The river must be imagined, also, as being constant in width and straight in its course, except for two semicircular bends. Again, as regards the difference of the rate of travel at the centre as compared to the two sides, the stuff in a Hollander obeys the same laws as the flow of a stream, and this will be rendered more evident on examination of the following table :—

Table XVII.

Table showing the Relative Rates of Travel of the stuff at the three positions, and at the three periods of Beating above mentioned, when the lowest rate of travel is reduced to 100.

Fig. 11.		Beginning.	Half-time.	At finish.
L	Outside	100	110	120
N	Middle...	123	140	151
P	Inside (mid-feather) ...	103	117	127
	Mean	109	122	133

Mean of all = 121.

For the purposes of comparison of the rates of flow at the different points and at different periods, the lowest rate of flow is reduced to 100, so that all figures can be directly compared with same.

It will be noticed that the slowest rate of flow is at the commencement of the beating, and at the point farthest away from the mid-feather. The next to this is at the point in contact with the mid-feather, which is about 3 per cent. faster in its rate of flow at the commencement.

The centre flow was 23 faster than the outside edge, and about 20 faster than the inside edge. This is accounted for by the fact that there is a retardation of the flow on the edges, due to the friction on the sides, and no doubt the relative rate of flow on the edges as compared with the centre would depend, not only upon the composition and consistency of the stuff in the beater, but also upon the roughness of the surface of the beater itself. If the beater is very smooth, of course, the friction would be less, and the difference between the rates of flow at the centre and the edges would be less also.

At half-time the stuff on the outside edge is flowing 10 quicker than at the commencement, and on the inside, next the mid-feather, 15 quicker than at the commencement.

At the middle there is an increase of rate of flow of 17; and, furthermore, the stuff in the middle is travelling 30 faster than the stuff on the outside edge.

At the finish the stuff is travelling 20 faster on the inside than at the commencement, or 10 faster than at half-time; that is, it shows a uniform increase.

The middle and inside differ from the outside in that they do *not show* a uniform progression in increase of speed, but they

counterbalance one another in such a way as to insure that the *average* rates of speed during the three periods are fairly uniform in progression.

As regards the vertical height, the stuff has to be lifted by the roll. This cannot be arrived at by taking the levels of the stuff at different parts. You will notice that there is not a great deal of difference between the level of the stuff before, and after it reaches the roll. I have taken an outside figure for the lift of the stuff. The bed plate being situated 6 ins. above the bottom of trough of beater, it might be argued that the difference between this level and the level of the top of back-fall is the vertical lift. But I would suggest that the stuff is hardly like water, and that, as a consequence, the blades of the roll exercise a pull upon the stuff as it approaches the roll. It might be fairly stated that it exercises a pull upon the stuff as it travels up the 6-in. inclined plane to the bed-plate, and that, as a consequence, the vertical lift should be taken as the difference between the level of top of back-fall and bottom of trough, which is a little under 1 ft. 6 ins. We are well on the safe side in reckoning it as 1 ft. 6 ins.

Data deduced from the foregoing, and upon which the calculations are based, are as follows:—

Mean time the stuff takes to make a complete revolution round engine (see Table XV.)	8·3 mins.
Total weight in beater (as above calculated) (p. 87)	8637 lbs.
Mean height the stuff is raised (on the above basis)	1 ft. 6 ins.

The foot-pounds per minute, according to this data, exerted by roll in raising stuff over back-fall are:—

$$\frac{8637 \times 1{\cdot}5}{8{\cdot}2} = 1580$$

which, converted into horsepower, is—

$$\frac{1580}{33{,}000} = \text{say } \tfrac{1}{2} \text{ h.p.}$$

This is converted into horsepower-hours per cwt. of stuff (air-dry fibre) as follows:—

$$\frac{0{\cdot}5 \times 60 \times 112}{570} = 5{\cdot}90 \text{ h.p.-h. per cwt. stuff.}$$

The actual amount of power consumed for circulation proper is therefore 5·90 in 14,560, or 40 per cent.

We have, therefore, of the power consumed in the Hollander for circulation and agitation—

Circulation proper, *i.e.* lifting the stuff over back-fall, as a consequence of which it flows by gravity round to the other side	40 per cent.
Agitation, *i.e.* churning about the stuff, beating air into it, and throwing stuff completely over Hollander and against roll cover, etc.	60 ,,

It was found that the total power consumption was 37·79 h.p.-h. per cwt. of stuff, and it is now known that the agitation accounts for 14·56 − 5·91, or 8·64 h.p.-h.

Therefore agitation is 8·64 h.p.-h. out of a total for beating of 37·79 h.p.-h., or 23 per cent.

If we take off the item given in a previous table for friction of steam-engine and shafting, it will be seen that agitation would amount to 8·64 in 33·1, or 26 per cent. of the total power consumed. This item is, in most cases, a dead loss of energy, as churning and splashing the stuff about does not help the beating proper, and is only of advantage in special instances.

It has taken all this elaborate working out and reasoning to show that *under the conditions of the above experiments there is at least* 26 *per cent. of power absolutely and entirely wasted with the Hollander*, and that this waste is due to the agitation of the stuff, as apart from the circulation. Some would aver, I think, that I have rather under than over estimated this loss, as I have assumed a vertical lift of 1 ft. 6 ins., or a lift equal to the difference in the level of the back-fall and the bed of the beater; this is done for reasons above stated. If, however, we take the difference between the height of the bed plate and back-fall as being the true vertical lift, the power of circulation becomes less, and, as a consequence, the power wasted in agitation becomes greater. Thus our figure for circulation becomes—

$$\frac{5{\cdot}9 \times 1}{1{\cdot}5} = 4 \text{ h.p.-h. per cwt. of stuff,}$$

increasing the figure for agitation to—

10·56 h.p.-h. per cwt. of stuff.

This would represent 32 per cent. of the total power consumption of the beater. It is presumed that engineers would agree that the latter mode of calculation is the more scientifically correct; *if so, we have to face the fact that of the total power consumed by Hollander in reducing air-dry sulphite to beaten stuff, practically one-third is uselessly expended in agitating the stuff.* As the process required for circulation and agitation is fairly constant for different materials in any given Hollander, it stands to reason that the *proportion* of power uselessly expended is less with materials that consume a lot of power in their reduction, such as strong rags. It follows, furthermore, that the percentage of power wasted is greatest with materials—such as straw and esparto—which require a comparatively small amount of power for their reduction. As a consequence, the Hollander would be an extravagant engine for the latter materials, but much less so for strong rags.

It can easily be seen how it is that an engine with an independent means of circulation sometimes shows a saving in power over the Hollander, for such materials as straw, esparto, and mechanical wood, because there is a relatively small *proportion* of power uselessly expended on agitation.

CHAPTER VIII.

The power expended in breaking-in, beating, and refining—The time of beating, output, and other data for five different materials beaten in Hollanders.

In the experiments about to be discussed, the Hollanders used have a capacity of 5 cwt., the beater roll a speed of 163 revolutions per minute, the roll a diameter of 3 ft., and the face of the roll a width of 3 ft., the approximate weight of the roll is 50 cwt., and it is furnished with bars of tempered steel to stand up to the work, and the bars are arranged in clumps of three. The conditions are, therefore, the same as with the materials, the treatment of which has been described in Chapter V.

TABLE XVIII.

Breaking, Beating, and Refining Power Tests on two Different Classes of Material.

	New twine ends.	New rags.
Capacity of beater	5 cwt.	5 cwt.
Power absorbed in motor and beater, running empty ...	4·1 h.p.	4·1 h.p.
Power absorbed in breaking ...	52·0 h.p.	64·6 h.p.
Time required for breaking ...	2 hrs. 15 mins.	3 hrs. 25 mins.
Power absorbed in beating ...	45·9 h.p.	51·0 h.p.
Time required for beating ...	1 hr. 45 mins.	1 hr. 30 mins.
Power absorbed in motor and Marshall refiner, running empty	12·6 h.p.	12·6 h.p.
Power absorbed in refining ...	58·0 h.p.	62·0 h.p.
Time required for refining ...	20 mins.	20 mins.

	New twine ends.	New rags.
Horsepower-hour per cwt. of stuff from raw to prepared fibre	46·71 h.p.-h.	63·61 h.p.-h.
Coal consumed in pulping 1 cwt. from raw to finished fibre at 3·3 lbs. (slack) per h.p.-h.	154·1 lbs.	209·9 lbs.

As regards the actual amount of power expended by each engine, and disregarding for the moment the power expended for a given output of stuff, the above table shows that the "breaking-in" of the new twine ends takes longer, and requires greater horsepower than the "beating," and, furthermore, that the power required for refining is greater still. With the new rags the power required to drive the breaker, as also the time of "breaking in," is greater than that of the new twine ends; but less power consumption for driving the beater is required than for driving the breaker, as also very much less time. The power consumed in driving the refining engine is not far short of the power consumed in driving the breaker, and is much in excess of the power required to drive the beater. So much for the actual and relative power consumption of the breaker, beater, and refiner for the two classes of material under review.

The *total* power consumption expressed in horsepower-hours in the case of "breaking-in" is arrived at by multiplying the horsepower consumption of the breaker by the time taken for "breaking in." A similar mode of calculation is adopted for the "beating," as also with the "refining." The figures shown in Table XVIII. (viz. 46·71 h.p.-h. and 63·61 h.p.-h. respectively) are arrived at by adding the three above figures together

I would point out again that the consumption of coal in pounds above given, is the equivalent of horsepower-hours in pounds of slack. The figure would be very much smaller with high-quality coal. In the above table the equivalent is 3·3 lb. (slack) per h.p.-h.; but with a high-quality coal it would, perhaps, be down to 2. Any papermaker can make a correction for this figure when he knows the evaporative efficiency of the coal he uses.

Table XIX.

Showing the Distribution of Power between the Breaking, Beating, and Refining for the Two Materials.

Material.	Breaking h.p.-h. per cwt.	Beating h.p.-h. per cwt.	Refining h.p.-h. per cwt.	Total of breaking, beating, and refining h.p.-h. per cwt.	Breaking.	Beating.	Refining.
					p. ct.	p. ct.	p. ct.
New twine ends ...	23·40	19·45	3·86	46·71	50·1	41·7	8·2
New rags	44·18	15·30	4·13	63·61	69·3	24·1	6·6

The above table gives the figures as previously shown in Table XVIII., calculated for the horsepower-hours per cwt. of stuff. It furthermore shows the distribution of the power as between "breaking," "beating," and "refining." It will be noticed that in the case of the new twine ends, 50·1 per cent. is expended in the "breaking," and 41·7 per cent. in the "beating," the ratio being practically as 5 is to 4, or, in other words, the power consumption for the "breaking" is 25 per cent. greater than the power consumption per hundredweight for the "beating." In this case the cost of power for "beating," as compared with that of "breaking-in," is roughly in the proportion of 1 to 3. In other words, in such strong materials as new rags, it cost nearly three times as much for power to do the "breaking-in" as to do the "beating." It should be borne in mind that the distinction between "breaking in" and "beating," or, rather, the dividing line, is purely arbitrary. It might be possible to state that a certain expenditure of power is necessary from start to finish; but nobody can lay down the law as to the proportion of power to be expended as between the "breaking in," "beating," and "refining." This will of necessity vary with the custom and conditions of each mill.

The refining in the above instance is a minor item, being only 8·2 per cent. of the total power consumption in the case of the new twine ends, and 6·6 per cent. in the case of the new rags. It is only resorted to as a final finish to brush out the stuff. This is by no means the universal custom, as many mills put a lot of work upon the refiner. In some cases it may be said to do from one-third to one-half the beating.

Referring back to Table XVIII. (p. 94), it will be noticed

that the power consumption by the breaker or beater when running empty is 4·1 h.p. Table XX. shows the ratio which the total power consumption bears to the power consumption of the beater, breaker, or refiner, when running empty, and is calculated from Table XVIII.

Table XX.

Showing how Power is apportioned as between the Friction of Machine and the Breaking-in, Beating, and Circulation, etc.

	Breaking.		Beating.		Refining.	
	Engine friction.	Breaking-in, circulation, etc.	Engine friction.	Beating, circulation, etc.	Engine friction.	Refining.
	p. ct.	p. ct.	p. ct.	p. ct.	p. ct.	p. ct.
New twine ends ...	7·8	92·2	8·8	91·2	21·7	78·3
New rags	6·3	93·7	8·0	92·0	20·3	79·7

It will be noticed that for breaking and beating with the two classes of material under observation, about 8 per cent. of the power is consumed by the "engine friction," the other 92 per cent. being expended in the actual work, which includes the beating, circulation, agitation, as well as the friction of the bars against the bed plate.

On looking at Table XVIII., it will be noticed that the power absorbed by the motor and Marshall engine running empty is 12·6 h.p., or, roughly speaking, three times that of the motor and Hollander running empty, and it consequently bears a higher ratio to the power consumption. The result is that the engine friction is, roughly speaking, 20 per cent. of the total power consumption in the case of these two materials.

Table XXI.

Rate of Output in lbs. per hour for Breaker, Beater, and Refiner, calculated from Table I.

	Breaker.	Beater	Refiner.
New twine ends ...	249 lbs.	320 lbs.	1680 lbs.
New rags	164 „	373 „	1680 „

The above table gives the total output, or rather the rate of output per hour, of the breakers, beaters, and refiners calculated from Table XVIII. This is arrived at in the case of the "breaking in" and "beating" by taking the capacity of the Hollander, and the time that it takes to get the engine off, and in the case of the "refining" the time that it takes to pass the contents of one Hollander through the refiner.

With the new twine ends, the output of the breaker is greater than that of the new rags, as might be expected. In the beater the orders are reversed, the output of the beater being less with the new twine ends than with the new rags; and with the refiner the output is the same in both cases, as it took 20 minutes in each case to pass the contents of a 5-cwt. engine through.

Table XXII.

Showing the Total Expenditure of Power from Start to Finish of Beating, and the Ratio of Power consumed in each Class of Material, lowest as 100.

	H.p.-h. per cwt. of stuff beaten.	Relative power consumption when lowest equals 100.
Sulphite wood	12·52 ...	100
Manilla rope	23·36 ...	187
New jute threads	26·34 ...	210
New twine ends	46·71 ...	373
New linen threads	53·83 ...	431
New rags	63·61 ...	509

The above table, XXII., brings all materials together for comparison, including those discussed in Chap. V. The first column gives the total power consumption from start to finish in horse-power-hours, the power consumption for the least being at the top. For the purpose of comparison, sulphite wood, which is the least, is expressed in second column as 100. This shows the following relationships:

Manilla rope requires ...	87 %	more power	than	sulphite wood.
New jute threads require	110 %	,,	,,	,,
New twine ends require	273 %	,,	,,	,,
New linen threads require	331 %	,,	,,	,,
New rags require ...	409 %	,,	,,	,,

Thus it will be seen that the consumption of power for the *reduction of* sulphite wood is only about half that of new jute

threads, and considerably less than a quarter that of new linen threads, and only about one-fifth the quantity required to reduce new rags to pulp. This fact alone, apart from any other consideration, must very materially favour the use of wood pulp as against most other materials. The difference will be even greater in beaters having an independent means of circulation. The Hollander is generally acknowledged, speaking comparatively, to be a more economical machine for treating strong rags than for weak material. And, *vice versâ*, it is regarded, on the other hand, as an extravagant machine for materials which do not require so much reduction, as in the case of "chemical," but more particularly in the case of "mechanical." It is probable, therefore, that we should see a greater difference between sulphite wood and new rags, for instance, if all these materials were tried and compared in another form of beater.

There is some considerable risk of the foregoing statement being misunderstood. When I state that the Hollander is a more economical machine for treating one particular class of material, I merely wish to convey that it shows up to better advantage as against other types of beater with that particular class of material.

TABLE XXIII.

Showing the Duration as well as the Relative Time for each Treatment when Total Time is reckoned as 100.

	A. Breaking time.	B. Beating time.	C. Refining time.	D. Total time of all three operations.	E. Total breaking time.	F. Total beating time.	G. Total refining time.
	h. m.	h. m.	m.	h. m.	p. ct.	p. ct.	p. ct.
Sulphite wood ...	—	2 30	30	3 0	—	83	17
Manilla rope ...	2 20	1 20	20	4 0	59	33	8
New jute threads ...	1 45	1 15	20	3 20	53	37	10
New twine ends ...	2 15	1 45	20	4 20	52	41	7
New linen threads ...	3 5	1 50	20	5 15	58	34	6
New rags	3 25	1 30	20	5 15	82	66	6

Table XXIII. gives a comparison of the time devoted to each operation; the first three columns (A, B, C) give the actual time, and D gives the time of all three added together; E, F, and G are *calculated from* A, B, C, and D.

With sulphite wood, 83 per cent. of the total time is devoted to the beating, leaving 17 per cent. for refining, but it will be noticed that the refining takes longer in the case of sulphite wood than with the other materials; with the manilla rope, 59 per cent. of the total time is taken up by the "breaking-in," 33 per cent. by the beating, and only 8 per cent. by the refining. There is not a great deal of difference between manilla rope, the new jute threads, and the new twine threads as regards the *percentages* of time devoted to each operation, but, as will be seen, there is a considerable difference in the *actual* time devoted to each operation. With the new rags a larger proportion of time than with any of the others is given up to the "breaking-in," reducing the time for actual beating to only 28 per cent. of the whole. The average amount of time devoted to the refining is about 8 per cent. of the total time.

It must be pointed out that the actual refining takes a very short time, being only that which the stuff takes to pass through the refiner. But the time here given is that necessary to pass the contents of one engine through the refiner; in the case of the "breaking-in" and beating the time given is the actual time of treatment. With any form of *rag* the "breaking-in" would naturally require a considerable proportion both of time and power. But with thread, the proportion of power for "breaking-in" would, or should be, less than with rag, for the simple reason that the function of "breaking-in" is to reduce the rag or broken fabric to the condition of thread, or spun yarn. Thread of any kind may consequently be regarded as broken-in or partly broken-in stuff.

Table XXIV.

Showing the Total Time required for beating each Class of Material, and the Relative Total Time for each Class of Material when the Least Time is reckoned as 100.

	Total time for beating and refining.	When least total time = 100.
Sulphite wood	3 hrs. 0 min.	100
New jute threads	3 „ 20 „	111
Manilla rope	4 „ 0 „	133
New twine ends	4 „ 20 „	144
New linen threads	5 „ 15 „	175
New rags	5 „ 15 „	175

Table XXIV. gives a comparison of the time of treatment for each raw material, taking the least time, viz., sulphite wood, at 100. It will be noticed that the new jute threads take 11 per cent. longer, manilla rope 33 per cent. longer, new twine ends 44 per cent. longer, and the new linen threads and new rags being equal in time and taking 75 per cent. longer for the total time of beating than sulphite wood.

On comparing Tables XXII. and XXIV., it will furthermore be noticed that material taking the least power per cwt. of stuff treated also takes the least time, and that the two materials taking the most power have been longest in treatment, and that the other materials arranged themselves in this order, with the exception of new jute threads and manilla rope, which are transposed.

Table XXV. overpage deals more particularly with the engines themselves, or, rather, the power absorbed by each engine apart from output. In Column A the time of treatment is represented. Column B gives the horsepower absorbed by the breaker taken from Table XVIII., etc.; likewise Column C gives the horsepower absorbed by the beater; and Column D the horsepower absorbed by the refiner.

In order to arrive at the mean horsepower absorbed during the treatment, the total horsepower-hours per cwt. is taken, which, when multiplied by the capacity of the beater, gives the total average horsepower-hours for the whole treatment. This, when divided by the total time of treatment, gives the total average horsepower the mechanism has absorbed during the treatment of each class of material. This is shown in Column E. Column F shows the order of time; Column G, the order in which the averages came out in Column E.

It will be noticed that the least average power developed during the treatment is the one requiring the least time, and the most average power developed during the treatment is the one occupying the most time. The intermediate ones fall fairly in order.

Messrs. R. and W. Watson have been good enough to determine the figures for new twine ends and new rags, as given in Table XVIII. I would repeat here that for the opinions expressed and conclusions arrived at, with which many, possibly, do not agree, I hold myself solely responsible.

TABLE XXV.

Showing the Power required per Engine, and the Mean Power during the whole of the Beating for each Class of Material.

	A. Total time of beating, etc.		B. Breaker.	C. Beater.	D. Refiner.	E. Mean power absorbed, arrived at by dividing total h.p.-h. per beater by the total time.	F. Order of time (Col. A) with least, as 1.	G. Order of power (Col. E) with least, as 1.
	h.	m.	h.p.	h.p.	h.p.	h.p.		
Sulphite wood	3	0	—	30·0	25·25	$\left\{\frac{12·52\times7}{3·0}\right. = 29·19$	1	1
New jute threads	3	20	41·0	38·75	34·5	$\left\{\frac{26·84\times5}{3·33}\right. = 39·50$	2	3
Manilla rope	4	0	25·3	31·6	47·0	$\left\{\frac{23·36\times5}{4}\right. = 29·20$	3	2
New twine ends	4	20	52·0	45·9	58·0	$\left\{\frac{46·71\times5}{4·33}\right. = 53·90$	4	5
New linen threads	5	15	55·25	42·6	63·0	$\left\{\frac{53·83\times5}{5·25}\right. = 51·25$	5	4
New rags	5	15	64·6	51·0	62·0	$\left\{\frac{63·61\times5}{5·25}\right. = 60·60$	6	6

CHAPTER IX.

Comparisons of large and medium-sized Hollanders when beating hard and soft stock.

I AM indebted to Mr. J. Youle for details of trials with a large Hollander made by Messrs. Bentley and Jackson, which is used as a washing and beating engine, and furnished for the manufacture of rope and jute papers. He considered, however, that, for hard stock, the present roll, which weighs over 10 tons, is too heavy. There is every reason to suppose that, with a lighter roll, the results would be far more satisfactory from the strength point of view. A 7-cwt. Hollander gives a stronger paper, presumably on account of the roll being lighter. The rope stock in the 7-cwt. Hollander, when washed and beaten in 7 hours, shows a breaking-strain of 43 lbs. on a $\frac{5}{8}$-in. strip. The stuff in the large Hollander, when furnished with 1 ton of rope stock and washed and beaten in 9 hours, shows a breaking strain of 35 lbs. on a $\frac{5}{8}$-in. strip. The difference in the strength of the two papers Mr. Youle attributed to the roll of the very large Hollander being too heavy.

From information supplied I have constructed the following table :—

TABLE XXVI.

Comparison of the two Bentley and Jackson Hollanders on Rope Papers.

Hollander of 7-cwt. capacity.		Hollander of 20-cwt. capacity.
45 h.p.	... ...	75 h.p.
7 hours.	... ...	9 hours.
45 h.p.-h. per cwt.	... ...	33·7 h.p.-h. per cwt.

Saving 25·1 per cent. by using 20-cwt. beater in place of 7-cwt.

The trials on the 20-cwt. and 7-cwt. Hollander are done on exactly the same stuff, which is all manilla rope. The sample papers from the two Hollanders I have before me. In general appearance they are very much alike. They show very excellent results, as can be seen by the official tests made by the Berlin *testing house.*

Mr. Youle feels certain that further economy would be obtained on the large beater if the roll was made lighter, say, 72 ins. on the face, and 54 ins. diameter, and to weigh about 5 tons.

The amount of power required on these very large Hollanders is nothing near so great when beating soft stuff, or when it is furnished with all folded "news" or issues, and 5 per cent. clay and 5 per cent. yellow ochre, so as to brush out before passing on the refiner. Under these circumstances the beater is capable of holding the enormous charge of 33 cwt. No doubt the power consumed is far less under these circumstances; but, as I have not the figure in the case of this soft stuff, to be on the safe side, I am taking the Hollander at the same horsepower as with the rope. On this basis the following are the details as against hemp :—

TABLE XXVII.

Bentley and Jackson's large Hollander.

Hemp.		Wood and Papers.
20 cwt.	... ...	33 cwt.
75 h.p.	... ...	75 h.p.
9 hours.	... ...	$1\frac{1}{2}$ hours.
33·7 h.p.-h. per cwt.	... ...	3·41 h.p.-h. per cwt.

Saving of 90 per cent. or more when working on wood or papers as against hemp paper stock.

From the results it would appear that we are justified in concluding that less than one-tenth of the power is required for brushing out papers as compared with beating rope. Table XXVII. shows us that by using a 20-cwt. Hollander 25 per cent. of the power is saved, as against the 7-cwt. Hollander. In all the above trials the stuff goes through a refining engine after leaving the engine. The roll of the 20-cwt. Hollander is 5 ft. 9 ins. diameter and 6 ft. 6 ins. on face, and furnished with 96 bars, the speed being 112 revolutions per minute.

The foregoing trials speak well for very large Hollanders both for soft and hard stock, provided that the question of weight of roll, etc., is properly studied to meet various requirements.

These results have surprised me very much, and have inclined me to the opinion that the last word has not yet been said about the Hollander, both in regard to output and economy of working. Future developments will show how far further economies may be effected.

CHAPTER X.

Trials to determine the relative merits of stone and metal beater-bars.

MESSRS. R. AND W. WATSON, of Linwood, Renfrewshire, who were good enough to supply me with details of trials on different classes of raw material in their 5-cwt. and 7-cwt. beaters when using rolls with steel bars, have now supplied me with details of trials, comparing the power absorbed, time required, etc., when using a stone roll as against a steel roll, the stone roll being Schmidt's Patent Basalt Lava Beating Roll.

With the 5-cwt. beaters the speed of the beating roll is 163 revolutions per minute, the diameter of the roll is 3 ft., and the width of the face of the roll is 3 ft., the approximate weight of the roll being 50 cwt., furnished with bars of tempered steel to stand up to the work, the bars being arranged in clumps of three. The rolls in the 7-cwt. beater make 140 revolutions per minute, their diameter being 4 ft. 3 ins., measuring 4 ft. 3 ins. on face. The approximate weight of the roll, which was provided with steel bars, was 52 cwt., but I am not acquainted with the present weight when furnished with stone roll.

TABLE XXVIII.

Beater Trial.

Each engine was furnished with 50 per cent. mechanical wood, and 50 per cent. unbleached sulphite wood.

	STEEL ROLL.	STONE ROLL.
Voltage of motors	230	230
Ampères (average)	67	185
Electrical horsepower (average)	20·6	57·0
Weight of stuff in engine ...	5 cwt.	7 cwt.
Time taken to beat stuff ...	3 hours	$1\frac{1}{2}$ hours.

From the above it will be seen that the 5-cwt. beater with the steel roll gives an average output of $1\frac{2}{3}$ cwt. per hour.

Steel roll beater $= 1\frac{2}{3}$ cwt. per hour @ 20·6 h.p.-h.
$= 12·3$ h.p. per cwt. of beaten stuff.
Stone roll $= 4\frac{2}{3}$ cwt. per hour @ 57·0 h.p.-h.
$= 12·1$ h.p. per cwt. of beaten stuff.

Actual increase per beater in hundredweights of output per hour—

$4\frac{2}{3} - 1\frac{2}{3} = 3$ cwt. per beater.

Greater output per hour, per beater, by use of stone beater rolls—

1·66 : 4·66 : : 100 : 280

For every 100 lbs. of output with 5-cwt. beater with steel roll, the 7-cwt. beater with stone roll gives, therefore, 280 lbs. in the same time.

Assuming that 5-cwt. and 7-cwt. beater with steel rolls would take the same time to beat an engine full; in order to arrive at the increased output of beater of any given size we must make the following correction $\frac{280 \times 5}{7} = 200$. It comes to this, therefore, that every 100 lbs. becomes 200, and the output is exactly doubled.

The saving in power, due to use of stone beater roll, is as follows :—

12·33 : 0·23 :: 100 : 1·54, or 1·54 per cent. of total power consumption.

There is then a slight saving in power per ton of output in this case, but inasmuch as the trial with the stone roll is made in a 7-cwt. beater in comparison with a 5-cwt. beater, we should expect a slight economy in any case. We must therefore conclude that there is practically no saving in power.

In order to determine whether the introduction of the stone roll effected any marked difference in the character of the beaten stuff, I requested Messrs. R. and W. Watson to send me two samples of stuff—one beaten with the steel roll, and the other with the stone roll, in other respects there being no difference in the stuff.

I examined both these samples carefully under the microscope, and could detect practically no difference in the character of the beaten fibres. I then made up a number of sheets from each lot on a hand mould, and chose sheets of equal thickness, which were *tested for strength.* The "stone roll sheets" averaged 6·24 lbs.

per inch width, and the "steel roll sheets" averaged 7·67 lbs. per inch width, the result showing somewhat in favour of the steel roll.

I do not regard this difference of importance, because, as we have already seen, the larger beater with heavier roll is liable to give a material of less strength, and the difference is not great. There was, furthermore, practically no difference in the "feel" of the two samples.

Assuming that there is no difference in the character and quality of the stuff got by the stone roll and steel roll, we are able to arrive at the following conclusions.

With the stone roll the stuff is much less time in process of beating, but there appears to be no appreciable advantage in saving of power. A given number of beaters will give a much greater output; therefore, wear and tear, interest and depreciation, etc., per ton of stuff beaten should be much less with the stone roll, provided that the maintenance of the stone roll compares favourably with that of the steel—a point upon which I have at present not sufficient information to form an opinion. If the stone roll were adopted in an old mill, a number of the beaters could be thrown out, in consequence of the greatly increased output of each individual beater.

In a mill of insufficient beating power, or in a mill where it is thought desirable to increase the beating power, the same might be accomplished by putting in stone rolls instead of by adding more beaters. In a new mill fewer beaters would be required.

Taking the foregoing trials as a basis, a battery of beaters giving an output of 100 tons per week of beaten stuff with steel beater bars could be increased to 200 tons per week with stone rolls, but the power required would have to be increased in a like ratio.

A large firm of papermakers from another part of the country, whose name I am not privileged to mention, have given me in general terms their opinion of the stone roll as the result of their trials, which opinion practically confirms the results above recorded.

It is when producing special effects that the difference in the character of the beating may be noticed. Some papermakers have found it difficult to believe that imitation parchment and greaseproof papers can be produced without something being added to the pulp. On examining this class of paper, made by the aid of the stone beater roll, under the microscope, after merely moistening it in cold water and careful separation, the wood

fibres of which the papers consist appear to be flattened, and to possess longitudinal flutings, as though each fibre had been taken and pulled lengthwise. If reagents are used these marks disappear. A particular kind of pulp is needed to produce the transparent effect. The greaseproof qualities appear to accompany the parchment-like qualities, so that one cannot be produced without the other.

The photomicrograph (Fig. 13) shows the fibres separated. It will be noticed that, in addition to the intact wood fibres, there is a mass of *débris*. This is wood fibre rubbed to a kind of gelatinous mass by the action of the stone roll. The roll appears to be twofold in its action. It appears to flatten some fibres, and to rub others to pieces. The pieces occupy spaces in between the flattened fibres, and if the right kind of pulp be chosen, a transparent greaseproof paper is produced. This sort of behaviour, I am informed, is greatly assisted by beating the stuff direct from the digesters.

Fig. 14 shows the paper intact.

Fig. 15 is split in accordance with the method suggested by Mr. Rowland Green. It is so thin as to constitute practically one layer of fibres. Between the large fibres are light patches which show interlacing of the reduced masses of fibres above referred to. A section, if stained with iodine, shows these gelatinous masses a very deep colour. The bismark brown appears to stain the bleached pulp more than the unbleached.

Some words of explanation are needed in regard to the relative merits of basalt lava stone and steel bars. It must be borne in mind that the two lots of stuff prepared and converted into paper on a hand-mould, and tested for strength, were prepared not for hand-made but for machine-made paper, and it does not necessarily follow, therefore, that the results would have proved the same had the two lots been passed over the paper machine. I am informed, on good authority, that with stuff from the stone roll, the paper is more uniformly strong than if it were made from stuff prepared by steel rolls; that is, the difference between the breaking strain in the machine and cross directions is less, and, at the same time, the machine-made paper stands in both directions a somewhat greater strain. I have not had the opportunity of verifying this statement. Furthermore, in discussing the question of strength, it has been suggested to me that when comparing the strength-giving qualities of the two it would have been fairer to have compared papers beaten by each in the same length of time. For instance, if it is the custom to beat for

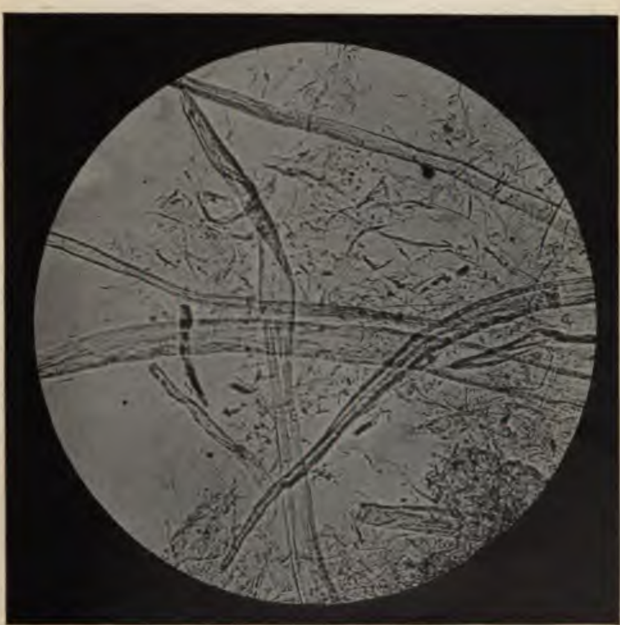


FIG. 13.—Separated fibres of greaseproof paper (unstained), mounted in glycerine. Magnification, 150 diameters.

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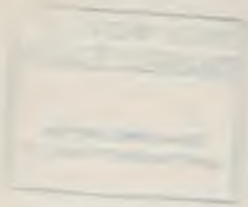


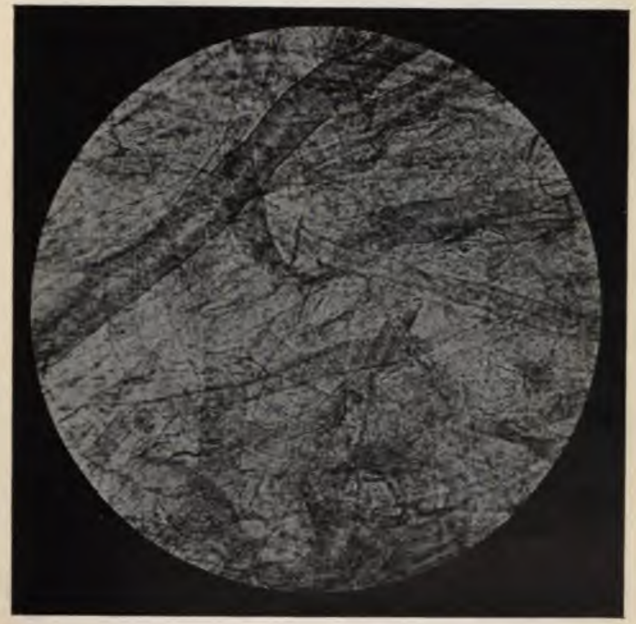


Fig. 14.—Greaseproof paper. Fibres rendered visible by staining and mounting in glycerine, showing fibres as they appear in the paper with light behind. 30 per cent. bleached, 70 per cent. unbleached cellulose. Magnification, 150 diameters.

To face page 108.]

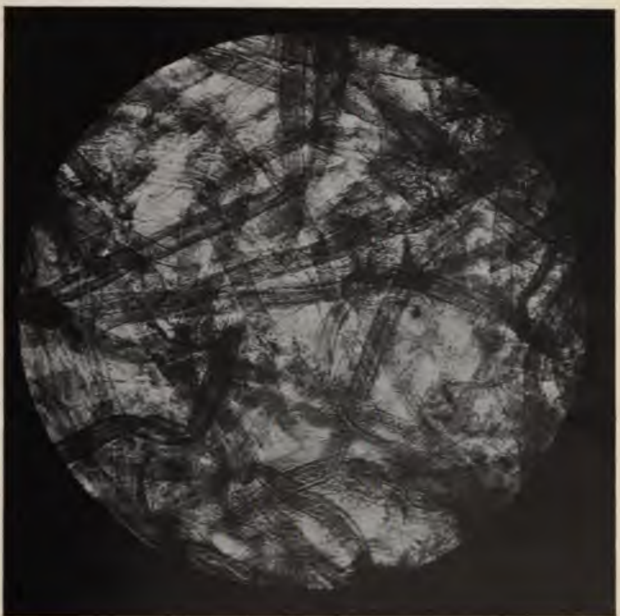


FIG. 15.—Split section of very transparent greaseproof paper. Stained in bismark brown. Mounted in glycerine. Same paper as Fig. 14. Magnification, 90 diameters.

To face page 108.]

3 hours with the steel roll, the same time should be given with the stone roll. Under such circumstances, the stuff is said to be much stronger with the latter. If, then, the time of beating with the stone roll is reduced to 2 hours, the stuff is still further reduced down to $1\frac{1}{2}$ hour, the strength is somewhat in favour of the stone roll, as against 3 hours with the steel roll; whilst if the time is still further reduced with the stone roll down to $1\frac{1}{4}$ hour, the stuff is still serviceable, but inferior to the steel roll stuff. The strength is, therefore, a question of relative time. I cannot agree with this suggestion of equal times for testing relative strengths, because with some strong stuffs it has been found in practice impossible to keep the stuff in so long, the stone roll rendering it too greasy to work on the paper machine.

Messrs. R. and W. Watson have favoured me with their opinions on one or two points. They do not think it would serve any good purpose to make theoretical comparisons of the results to be obtained from two beaters of unequal dimensions; nor do they think it profitable or instructive to speculate on the possible difference in the strength of sheets made on hand-mould or paper machine. They find, from practical tests, that very strong fibres prepared by the stone roll become too greasy to work on the machine if they are kept running in the beater the equivalent time taken to prepare with the ordinary roll. As to the comparison of power given in the previous chapter, I cannot agree that there is no good in making a comparison. We have a good deal of data for different sizes—sufficient, I think, to enable us to form some fair judgment, although it must be admitted that a comparison of equal sizes would have been much more satisfactory.

Under equal conditions rags, ropes, woods, manillas, and jutes can be milled with the stone roll, and a rather better paper made in exactly half the time. The stone roll has quite the opposite effect of a steel roll: it bruises but does not cut. Providing that the life of the stone roll can be guaranteed, it has a great many advantages over steel for the working of weaker fibres. It is possible to use greater freedom with the roll without spoiling the pulp. It can be put hard down on the plate without discolouring the pulp, and renders it possible to make a better sized paper with, say, 3 per cent. less size and starch. The *pros* and *cons* have to be carefully weighed. It is not possible to express the merits of the two in so much horsepower-hour, although such figures are, when taken in conjunction with various other matters, of considerable assistance in forming an opinion. Of course, if you

can do with half the beaters by beating in half the time, and so doubling the output of each individual beater, you can do with much less labour, less space, less shafting, less transmission of power for any given output per week.

I have a great deal of information on the subject, which could hardly form the subject to be dealt with in this volume.

I desire, above all things, to be absolutely fair and just in putting forward statements of this kind, and if any readers of this work could enlighten me on the subject, I should be pleased if they would communicate with me.

CHAPTER XI.

Trials with breakers, Reed beaters, and Kingsland refiners.

THIS chapter deals with power tests on the Kingsland refiner, the Reed beater, the Taylor beater, also breakers, beaters, and bleachers of ordinary type.

It is evident that no two mills would conduct their tests on exactly the same lines; they must be guided in a large measure by the conditions under which they work; hence it is no easy matter to bring the results of the different tests which have been submitted to me under a common denomination for purposes of comparison.

Where it is necessary in a large measure to allow tests to speak for themselves, as it will be to some extent in those before us, it is at least necessary for me to give some details in regard to the machines which are tested, as to the capacity, speed, size, and weight of rolls, etc., in order that one set of trials may be compared with another.

In the tests now before us with the British Westinghouse motor, instead of reckoning 746 per horsepower, we have adhered to the formulæ used by the manufacturers who conducted the test, which formulæ is given at the head of the tables. They adopt 0·9 of the actual electrical horsepower measured to allow for the loss on transmission. It will be noticed that in previous tables of electrical measurements no allowance was made for this. In order, therefore, to express two sets of tables in a similar manner, it would merely be necessary for any reader to add one-ninth of the figures given below, or to deduct one-tenth of those given previously. I need hardly remind my readers also that no two sets of tests can be compared with one another, with a view of showing the relative economies of any beaters under examination, unless they furnish the extent to which each beating is carried, the proportion of the beating conducted by the beater. Such details are of particular importance when comparing the work of one mill with that of another. Then let it be remembered that even with chemical and mechanical wood there is much difference when furnishing beaters according to whether the sheets are dry or moist. Added to this

there is the fact that no two mills beat exactly alike: some leave the fibres longer than others; whilst some mills work from short-fibred pulps, others work from long-fibred, and produce strong papers. Hence, it cannot be said that a definite amount of power is required to reduce chemical or mechanical wood from the state of sheets of pulp to the condition of stuff for the machine, unless we can, at the same time, specify just the kind of pulp, whether moist or dry, and to what extent the beating has been conducted, also whether the stuff is to work "wet" or "free," etc.

In this section I have adhered to the practice of expressing the power consumption as horsepower-hours per cwt., instead of per 100 lbs. It is a more useful expression for most papermakers, as from this figure they need find no difficulty in arriving at the coal consumption per cwt. or per ton by the aid of data which they have, or should have, in respect to their own mill.

With these few words by way of explanation and warning, I will proceed to a description of the tests.

Table XXIX.

Tests made with Westinghouse Motor, Direct Current.

H.P., 36; volts, 110; amps., 264; revs., 560; $\text{B.H.P.} = \dfrac{\text{volts} \times \text{amps.} \times 90}{746 \times 100}$

Kingsland Refiner Tests, Nos. 1 to 6.

	Amps.	Volts.	Revs.	Net B.H.P.
First Test.—Load: 1 length 8″ shaft, 4 lengths 6″ shaft. Glossop refiner running empty. Tail pin on to keep disc clear. Pump on, but not lifting	250	117	132	35·28
Second Test.—Pump throwing. Disc as above	265	122	132	39·0
Third Test.—Tail pin taken off ...	350	122	132	51·51
Fourth Test.—Front plate put on to recorded load; being so much overloaded, no further pressure put on. Beaterman's limit for working being about 2½″ further round circumference of screw	380	122	132	55·93
Fifth Test.—Refiner running empty and washed out. Pump working; shaft moving ... ... From	200	125	132	30·1 on end
Varying to	230	125	132	34·6
Sixth Test.—Shafting running *empty.* Refiner belt taken *off* 1	90	130	130	14·1
2	—	—	—	13·75 (aver. 13·9)
3	—	—	—	13·86

No. 3 BREAKERS; REV. OF ROLLS, 140; AND REED BEATERS.

	Amps.	Volts.	Revs.	Net B.H.P.
Seventh Test.—Breakers running empty (first test)	100	121	132	14·59
Eighth Test.—Breaker, full load (filled in with 600 lbs. mech. and 140 lbs. sulphite)	300	121	132	43·79
Ninth Test.—Breaker belt off. Shafting running empty (second test) ...	95	120	131	13·75
Tenth Test.—No. 1 Reed Beater. Belts on, running empty. Screw propeller, 290 revs. Roll, 206 revs.	107	120	131	15·4
Eleventh Test.—Stuff let down from breaker. Roll down, average weight. Screw propeller, 270 revs. Roll, 206 revs.	325	121	132	47·4
Twelfth Test.—Beater belts off. Shaft running empty (third test) ...	95	121	132	13·86
Thirteenth Test.—Breaker belt on (amps. reached 450 in getting up speed = 65·6 B.H.P.). (Second test empty.)	100	121	132	14·59
Fourteenth Test.—Breaker filled in as second test above. Same furnish. 1st, 43·79; 2nd, 46·7; aver., 45·25 b.h.p....	320	121	131	46·7
Fifteenth Test.—No. 2 Reed. Belts on, running empty. Screw propeller, 175 revs. No. 2 Reed roll, 206 revs.	110	121	132	16·0
Sixteenth Test.—Stuff let down from breaker. Roll down, average weight. Screw propeller, 175 revs. Roll, 206 revs.	215	121	132	31·38

Summary of Beater Tests.

B.H.P. required to run shafting empty. Aver. of three tests	— — 13·9
B.H.P. required to run breaker empty—two tests ...	14·59 − 13·9 = 0·69
B.H.P. required to run breaker full—two tests ...	45·25 − 13·9 = 31·35
Power required to start breaker from rest reached ...	65·6 − 13·9 = 51·7

Summary of Reed Beater Tests.

B.H.P. required to run No. 1 Reed empty	15·4 − 13·9 = 1·5
B.H.P. required to run No. 1 Reed full	47·4 − 13·9 = 33·5
B.H.P. required to run No. 2 Reed empty	16·0 − 13·9 = 2·1
B.H.P. required to run No. 2 Reed full	31·38 − 13·9 = 17·48

Bleaching Engine, Paper Breaker, and Shafting.

	Amps.	Volts.	Revs.	Net B.H.P.
Seventeenth Test. — Empty shafting from rope pulley to west end: 1 length 8″, five lengths 6″	190	122	131	27·9
Eighteenth Test.—Put bleacher belt on; found load too heavy. Uncoupled at west side of Bleacher. Pulley left on, empty shafting: one length 8″, one length 6″. Bleacher empty	180	121	131	26·2
Nineteenth Test.—Filled in bleacher. (*Note:* Load ran up to 325 amps. through block of stuff moved on with stirring stick) ... From	275	121	131	40·14
To	325	121	131	47·4
Twentieth Test.—Empty shaft, 2 lengths as above. (*Note:* Shafting had been moved endways in bearings ¾″, probably causing extra friction)	125	121	130	18·2
Twenty-first Test.—Shafting to west end coupled as at Test 17, but all belts off	180	120	130	26·0
Twenty-second Test.—Paper breaker belt put on. Running empty ...	195	120	130	28·2
Twenty-third Test.—Paper breaker filled in	225	121	132	32·84

Summary of Bleacher Tests.

Power required to run bleacher empty, less shaft (see Tests 18 and 20)	26·2 − 18·2 = 8·0
Power required to run bleacher full, less shaft (see Tests 18 and 20)	40·14 − 18·2 = 21·94
Power required to run bleacher with roll partly blocked by lumps	47·4 − 18·2 = 29·2

Summary of Breaker Tests.

Power required to run shafting, as Test 21	—	—	26·0
Power required to run paper breaker empty	28·2	− 26·0 =	2·2
Power required to run paper breaker full	32·6	− 26·0 =	6·84

It will be noticed that the general plan of testing is to determine the amount of power absorbed by shafting, etc., which shafting may be altogether out of proportion to the amount necessary to drive the particular machines, but this is more or less immaterial. Then to test the machine running empty; then to *throw in the pump* or circulator; then to run the machine under

normal conditions; and finally, to test the machine with the maximum amount of power. The first six deal with the Kingsland refiner, made by the Glossop Ironworks Company, Ltd.

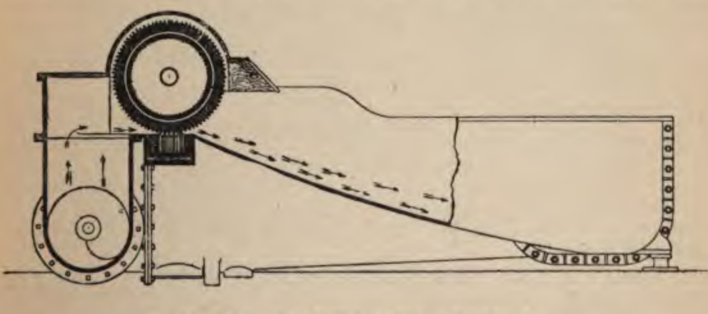
Next come tests 7 to 16 on the breaker and Reed beater, after which follows the summary of the breaker tests and Reed beater tests.

Tests 17 to 23 deal with the bleaching engine and paper breaker, after which following summary of these tests.

FIG. 16.

For the time being we will leave the Kingsland refiner, and deal in detail with the tests on the Reed beaters.

The Reed beater is generally made in standard size, in accordance with photograph, Fig. 16, sectional elevation, Fig. 17, and view from above, Fig. 18, as supplied by the makers, Messrs. James Milne and Son, Ltd. The rolls generally have 150 bars, and these bars vary from $\frac{3}{16}$ to $\frac{1}{8}$ in. in thickness. In some beaters the rolls have been 33 ins. in diameter with 138 bars, and the rolls are all 48 ins. long for the



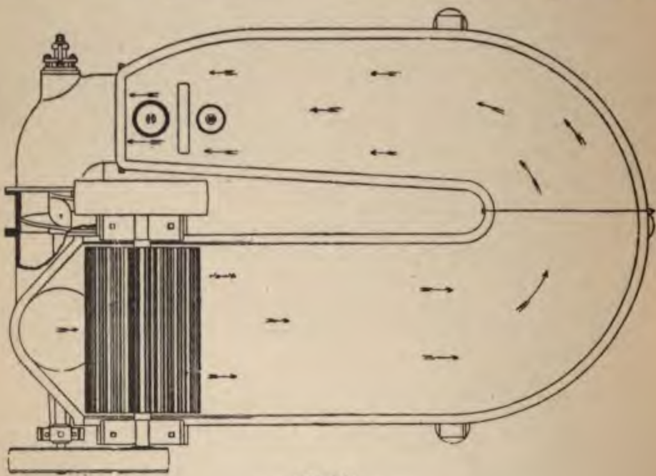
— SECTION THROUGH ROLL CHANNEL —

FIG. 17.

standard size of beater, but some larger ones have been constructed for special work.

As ordinarily worked, a Reed beater roll of 3 ft. diameter makes 225 *revolutions* per minute. The bed-plate is sometimes *made with bronze* bars and sometimes with steel bars, and they

are generally $\frac{1}{8}$ in. thick, with lead dividers. The screw or propeller is made of bronze, and makes between 125 to 140 revolutions per minute. The makers state that the pulp in a 6-cwt. beater is circulated round the beater in 2 minutes, at an expenditure of about $2\frac{1}{2}$ h.p. The pulp is lifted to a point slightly above the level of the bed-plate, and flows in between the roll and plate, and as the roll has only to perform the function of beating, it is of special construction. The bars are parallel, and



— PLAN —

FIG. 18.

are set at about $\frac{3}{4}$ in. pitch, and project about $\frac{3}{8}$ in. beyond the body of the roll.

Now, the tests with the Reed beater, as herein given, are instructive for the following reasons :—

Nos. 1 and 2 Reed beaters had a roll speed of 206 revolutions per minute, being rather less than that ordinarily employed. With No. 1 Reed, the screw-propeller was made to revolve at 270. With No. 2 Reed, the propeller revolved at 175 ; 175 is the speed ordinarily employed in the mill. The manager was anxious to ascertain what effect the increased rapidity of circulation would have upon the output, and he found that by increasing the screw-propeller from 175 to 206, he exactly halved the time of circulation

round the beater. It is generally supposed, I believe, that increased rapidity of circulation means greater output; or, which is the same thing, quicker beating; but these trials show that the time of beating was in no way diminished. No. 1 beater circulated in half the time of No. 2, but both took four hours to beat. This is not the only significant fact, as it will be evident, when examining these tests, that increased circulation means also increased power consumption, so that harm instead of good results from circulating quicker.

Note that the furnishing in these trials for the breakers is 600 lbs. of mechanical and 140 lbs. of sulphite. After this furnish has beén emptied into the Reed beater, it is, as I understand it, stiffened up with bleached wood.

The Reed beater rolls are 3 ft. diameter by 4 ft. wide, and weigh 3 tons, and are furnished with 150 steel bars, $\frac{1}{8}$ in. full in thickness. The bed plates are straight, with lead of $1\frac{1}{4}$ ins. in 4 ft. Their total capacity is 900 lbs. of air-dry fibre. The time of filling in takes 7 mins., and the time of emptying 12 mins., which are included in the total time of 4 hrs.

TABLE XXX.

Tests of Reed Beater summarized.

Capacity	900 lbs.
Time to fill in	7 mins.
Time to empty	12 mins.
Time between filling and emptying	3 hrs. 41 mins.
Total time of beating	4 hrs.
Output per hour	225 lbs.
Hours' consecutive work required to beat one ton	10 hrs.
Power required for beater and shafting—	
No. 1 (screw propeller), 270 revs. ...	47·4 h.p.
No. 2 „ „ 195 „ ...	31·38 h.p.
Normal power required per cwt. (No. 2, including shafting)	15·69 h.p.-h.
Normal power required per cwt. (No. 2, without shafting)	8·74 h.p.-h.

The above figures give a comparison of fast and slow circulation when *the shafting is* included.

On looking at the summary of Reed Nos. 1 and 2 (Table XXX.), which show the power consumption after the shafting is deducted, it will be noticed that No. 1 Reed takes practically double of No. 2. It is not fair to assume that the whole of this difference is due to increased circulation; some of it may be due to the roll having been down harder in No. 1 than in No. 2, but they are supposed to be working under similar conditions. The difference is so great as to make it evident that increase in the circulation enormously increases the power of consumption. Taking the shafting into account, the increase of power of consumption amounts to 50 per cent., or, by excluding it, 100 per cent.

I find it somewhat difficult to account for the greatly increased consumption of power when the stuff in the Reed beater is circulated at double the normal speed, but it appears to be in this wise: Under ordinary circumstances the screw-propeller has merely to raise the level of the stuff a little above that of the level of the bed-plate in order to occasion a flow just passing under the roll, and gravitation practically doing the rest. When the stuff leaves the bed-plate, it slides down the inclined plane and continues to flow until it reaches the screw-propeller again, the propeller merely propelling it for a few feet, equal to the length of the propeller itself, and again lifting the material just sufficiently to overflow the bed-plate. This is what happens, or appears to happen, under normal conditions. To occasion a flow or circulation all that is needed is to create a certain difference of levels on either side of the roll and bed-plate, this difference being just sufficient to promote the necessary circulation. But assuming now the circulation is doubled in speed, the result would be to raise the level of the stuff in front of the roll. It is conceivable that this raised stuff might reach the level of the spindle, because only a limited amount of material can pass through between the bars and the bed plate, and in order to fill the space in between the bars a head of stuff is needed.

If a beater of this description is over-circulated so that the roll is flooded with stuff up to the spindle it becomes in effect a Hollander. We have already seen that about one-third the total power in a Hollander for wood pulp furnish is uselessly expended. It is conceivable and highly probable that the stuff as ordinarily circulated in the Reed beater does not fill in the spaces between the bars of roll. If, however, the head of stuff is raised to level of spindle, the spaces between bars would probably be filled, and rate of circulation possibly doubled.

With such a head of stuff, as far as the front of the roll is

concerned, agitation may take place not unlike that of an ordinary Hollander. Hence, it would appear highly probable that increased speed, due to running propeller too fast, would result in the increased consumption of power, due not only to propeller, which, perhaps, is of minor importance, but to agitation of stuff by roll, which under normal circumstances is avoided.

The following figures will give some idea of the increased amount of work or absorption of power occasioned by causing the beater to be circulated above that of its normal or natural speed.

Let us assume that a Reed beater is made to circulate in half the normal time by increasing speed of screw-propeller, which increased speed has occasioned a difference in levels of 2 ft. Assuming that the beater holds 900 lbs. of dry fibre, and the dry weight is 4 per cent. on the wet weight, the wet stuff would be—

$$\frac{900 \times 100}{4} = 22{,}500 \text{ lbs.}$$

This circulates round beater once per minute, and each time or minute is lifted 2 ft. The propeller will have to do $22{,}500 \times 2 = 45{,}000$ ft.-lbs. per minute, apart from its own internal friction, etc.

$$45{,}000 \text{ ft.-lbs.} = \frac{45{,}000}{33{,}000} = \text{say, } 1\tfrac{1}{2} \text{ h.p. ;}$$

but as the increased consumption by doubling the circulation is a matter of some 16 h.p., some other cause must be at work. This is to be sought for in the agitation of beater roll occasioned by elevating level of stuff.

It would appear from trials previously cited that the amount of power expended in what I call useless agitation in a Hollander, apart from circulation proper, is somewhat as great as the power expended in actual beating. If, therefore, we convert a Reed into a Hollander, so to speak, by pumping up stuff against the roll to a high level, and so promoting a lot of churning, we might expect that the power consumption would be doubled; at any rate, this is just what has happened, as the power consumption (after deducting shafting, etc.) has increased from 17·48 h.p. to 33·5 h.p.

And, I ask, is it surprising that the doubled circulation has *not increased the rate* of getting off the stuff? Why should it?

The roll, with a given rate of speed, number of bars, and so forth, provided the pressure is applied the same in both cases, could not do any more work in the two hours the stuff is pumped round. It would appear possible with a beater of this class to alter the rate of beating by roll pressure, speed of roll, and so forth, but not by pumping round quickly.

I think these trials afford a useful lesson and one worthy of note by all those who are studying the subject.

It will be noticed that in the tests 1 to 6, Table XXIX., the Glossop or Kingsland refiner runs at 163 revolutions, and the column showing 132 revolutions refers to the revolutions of the motor.

In test 4, where it is stated that it is "much over-loaded," refers to the motor over-loaded, and not the refiner.

As to test 8, etc., in these experiments the beater was furnished with 740 lbs. of fibre only.

I am not able to account for the difference of the speed given by the makers of the Reed beater and the rate of speed actually used at the works. It will be noticed that the makers recommend the speed of 225 for a 33-in. diameter roll, whereas the revolution of the Reed beater roll in test No. 10 is 206.

Then again, in the trials, the normal propeller speed is 195 (15th test), whereas the makers recommend a speed of from 125 to 140, the increased speed to double circulation being 270, and not as stated, and the time of beating 2 hours and not 4.

Of course, the speed of the propeller must depend somewhat upon the kind of material that is being beaten, and, if it were possible, it might prove very advantageous if the speed of the propeller could be varied to suit different kinds of stuff.

I am of opinion that a great deal depends upon the proper speed of the propeller, and that to ensure the utmost economy this part of the subject should be carefully investigated.

The papermakers who made the trials double the rate of circulation by increasing the speed of the propeller, as we have already seen; but they are unable to tell me how long in each case it took for the stuff to make a complete circulation round the beater.

The makers state that one complete circulation can be made in 2 minutes by the expenditure of about 2½ h.p., and presumably this is accomplished under ordinary circumstances, when the propeller is making from 125 to 140 revolutions, which is much less, of course, than the rate of the propeller in the tests *before us.*

In the Kingsland refiner tests, Nos. 1 to 6, the output is about 11,000 lbs. per hour dry stuff. The power, including shafting—

$$\left.\begin{array}{l}\text{(No. 1), is } 51{\cdot}51 \\ \quad\;\; \text{,,} \qquad 55{\cdot}93\end{array}\right\}\text{making a mean of } 53{\cdot}72.$$

The power required per cwt. of stuff refined from above works out at 6·01 h.p.-h.

The difficulties of arriving at the exact figures here are due to the fact that a very large amount of the power is for shafting and run of the machine apart from actual refining. To get some idea

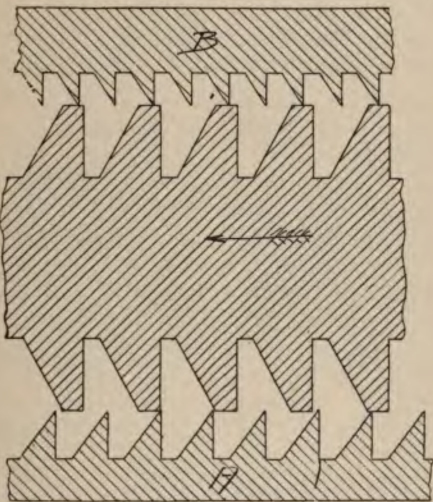


Fig. 19.—Part section through roll and plates.

of this it is best to represent the proportion, which works out roughly as follows:—

Proportion of Total Power.

For shafting	28 per cent.
For machine doing no work	22 ,,
For actual refining	50 ,,

The total power consumed per cwt. of output would be for refining, *without shafting*, about 4·3 h.p.-h.

The limits of variation according to the above tests may be expressed as follows:—

For shafting	13 to 14 h.p.
For pump	4 " 4 "
For refiner empty without pump ...	16 " 25 "
Additional for work of refiner	15 " 25 "

It must be noted that the maximum figures cannot be taken together, as these would not, in practice, necessarily occur simultaneously.

We are met with difficulties here in discussing the practice of refining, because the methods of different mills vary enormously, and the proportion of power expended by the refiner in comparison

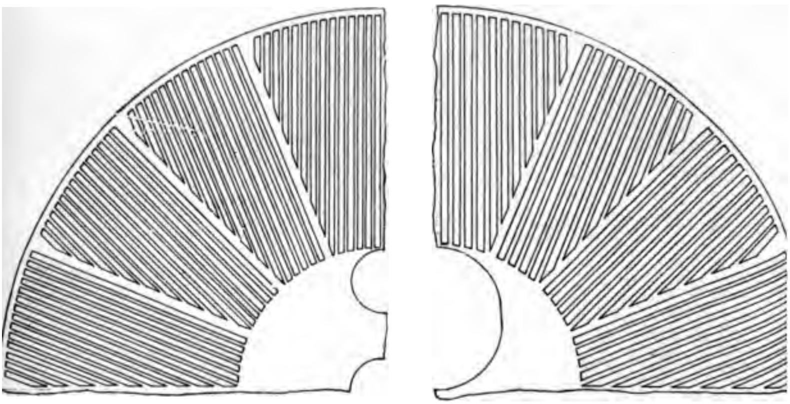


FIG. 20.

Part face view of back plate B. Part face view of front plate A.

with that of the breaker and beater also varies enormously, so that it becomes a matter of extreme difficulty to assess the efficiency of a refiner largely because it is impossible to measure the changes which have taken place in the passage of the stuff from the beater to the chests. Thus, by way of example, refiner A, consuming 3 h.p.-h per cwt., would be less efficient than refiner B, consuming 6 h.p.-h. per cwt., when B is doing more than double the work by way of reducing or "clearing" the fibres. Sometimes a refiner has very little to do, whilst at other times it takes

a large share of the beating, to the relief of the beater, and similarly the beater to the relief of the breaker, and *vice versâ.*

When the necessary corrections are made on the basis that the stuff was got off in a Reed beater in 2 hours all told, and was furnished with 740 lbs., the horsepower-hours per cwt. works out (with shafting) at

$$\frac{15{\cdot}69 \times 900 \times 2}{740 \times 4} = 9{\cdot}54 \text{ h.p.-h.}$$

and without shafting

$$\frac{8{\cdot}74 \times 900 \times 2}{740 \times 4} = 5{\cdot}31 \text{ h.p.-h.}$$

In the above case the refiner, with shafting, has consumed, roughly speaking, 6 h.p.-h. for each 10 h.p.-h. per cwt. consumed

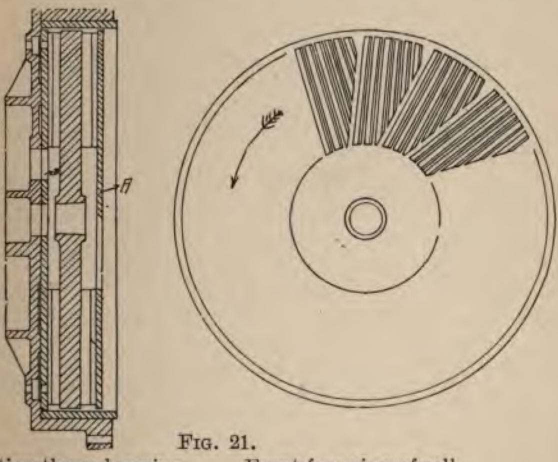


FIG. 21.

Section through casing, roll and plates. Front face view of roll.

by the Reed beater. In some mills the refiners take less and in others more in proportion; but in order to compare the above proportion to that given in previous trials, it would be necessary also to include the power of the breaker, bleacher, etc.

To *go into all* these points would occupy a great deal of

space. The figures are given in the tables, and any reader who is sufficiently interested can work them out for himself and make useful comparisons, not only with figures that have already been published in previous chapters, but with those he may have obtained from time to time in his own mill.

Figs. 19, 20, and 21 show arrangement of roll and plates of the Kingsland refiner from tracings supplied by the makers. These sections explain themselves. The back and front rolls are made of cast-iron, and until recently the rolls were made with steel bars cast in them; but now they are made entirely of cast-iron, as they are found to answer quite as well as when fitted with steel bars.

CHAPTER XII.

Trials with breakers, Reed and Taylor beaters.

THE tests recorded in this chapter were conducted at the same mill as those just described. These show electric and steam-drive compared side by side with breakers, Reed and Taylor beaters.

It will be noticed that two engines, in each case, have been taken. It stands to reason that it is better to take two engines than to take one in each case, as an average result of two is more likely to be dependable than the result from one only. Unfortunately, the figures are not quite complete in the third column, and one has partly to rely upon the summary of comparisons of the steam-power column to make up this deficiency.

We can, however, arrive at something useful and practical by a process of circumnavigation.

The tests given as ordinary experiments represent a small load with the roll just brushing, such as is often used for ordinary qualities. As this is frequently a "middle" load on roll, between "light" and "heavy," it may be taken as an average.

The figures 150·7 and 112·5 under the steam-drive column would appear to be very high. The figure 150·7 represents an average working load on the two Reed beaters, when beating with *all* the shaft for six engines running, but breaker and Taylor belts off.

The ammeter reading No. 2 is the one, so I am told, to go by; but as the No. 1 column had not been proved to be wrong, it was used at the mill for the "ratio" as calculated in the last column.

The furnish of all the above beaters was 90 per cent. sulphite pulp thickened up with 10 per cent. of "broke" papers taken straight from the machine.

The capacity of the Reed beaters was 900 lbs., and that of the Taylor's 1000 lbs. of dry fibre.

There are difficulties in summarizing these results. It will be

noticed that the power on the Reed beater is less than on the Taylor, but if allowance be made for the smaller time for "getting off" the stuff for the Taylor, and the greater capacity of the latter, the above figures, as they stand, show to the advantage of the Taylor.

I do not propose to show a strict comparison between the two, as I do not consider it possible to arrive at any definite conclusions, but the figures are nevertheless instructive. The comparison might be shown by anybody who would care to take the trouble, by allowing the same amount of power for shafting, etc., in the two cases.

The capacity of the breakers is 750 lbs., being furnished with 90 per cent. chemical and 10 per cent. broke. The breaker rolls are not provided with bars. The speed of the roll is 130 revolutions, the size of the roll is 4 ft. by 4 ft., and the weight about 3 tons.

Taking the No. 1 column and the breaker tests, if gear and shafting is included, the results can be seen at a glance and without calculation, because it happens that "heavy" load equals 100.

Of the total power, 43 per cent. is for gear and shafting.

(50 – 43) equals 7 per cent. for driving breaker.
(75 – 50) equals 25 per cent. for beating, agitating, etc.

It must be understood that, with the breakers, the roll is not put down at all, it does no "beating" as we usually understand the term, and the roll remains in a fixed position. It appears rather to paddle and agitate the stuff. The "heavy" load refers to filling in—*i.e.* putting in slabs of mechanized pulp or dry papers and sulphite sheets, etc. When these are broken up the breaker then takes the "mean" load.

It must be remembered that the gear and shafting belongs to all six engines. How are we then to apportion to each engine its proper ratio of shafting, etc.? Would it be fair to divide the amount, whatever it is, between the six engines equally, or apportion to each *pro rata* according to amount of power that each engine takes?

Table XXXI.

Showing Details of Power Tests for Reed and Taylor Beaters.

	Electric drive No. 1.	Ammeter No. 2.	Steam drive I.H.P.	Ratio I.H.P. to ampères.
Breaker Tests.				
Motor, gear and shafting only ...	43	55	59	1·372
Shafting and 2 Breakers, empty	50	62	—	—
,, ,, ,, heavy	100	120	119	1·19
,, ,, ,, mean	75	—	—	—
Reed Beater Tests.				
Shafting and 2 Reed Beaters roll up	105	125	—	—
Shafting and 2 Reed Beaters heavy	150	170	186·3	1·252
Shafting and 2 Reed Beaters mean Ordinary by experiment	128 97 } 112·5	—	150·7	1·339
Taylor Beater Tests.				
Shafting and 2 Taylor Beaters roll up	79	99	—	—
Shafting and 2 Taylor Beaters heavy	155	180	195·2	1·259
Shafting and 2 Taylor Beaters mean ... ... Ordinary experiment	117 90 } 103·5	110	112·5	1·087
	Mean of all the above ratios			1·223

My idea is that the engine, line of shafting, etc., with belts off, should be first indicated, and then indication taken with all beaters, etc., on, under average work. This would give the percentage to be added for shafting, etc. Thus, by way of simple example, say, engine and shafting = 50 h.p.; engine, shafting, and beaters = 250 h.p., 25 per cent. or one-fourth would have to be added to each reading for beater alone to show you what it takes, all told, with its quota of engine and shafting.

The *ratios of different* figures in No. 2 column appear to be

approximately the same as with No. 1 column, although the former range decidedly higher. The breakers here referred to are not the same as those referred to earlier in the work.

With all the above machinery running on heavy load, the steam-engine indicated 397·6 i.h.p. with line shaft running at 76 revolutions.

Equivalent i.h.p. for line shaft at 87 revolutions (which was, approximately, the speed maintained during all the above experiments), 455·2 i.h.p.

Calculated on the mean ratio, this equals 373 amps.

All beaters filled with stuff all the time.

Table XXXII.

Summarized from Table XXXI.

	Reed.	Taylor.
Capacity	900 lbs.	1000 lbs.
Time to fill in	7 mins.	7 mins.
Time to empty	12 mins.	12 mins.
Time between filling and emptying	3 hrs. 41 mins.	3 hrs. 18 mins.
Total time of beating	4 hrs.	3 hrs. 30 mins.
Output per hour	225 lbs.	286 lbs.
Hours consecutive beating to beat 1 ton	10 hrs.	7 hrs. 50 mins.
Beaters, including shafting—mean ...	75·35 h.p. per beater	56·25 h.p. per beater
Beaters including shafting. Rolls on heavy	93·15 h.p. per beater	97·6 h.p. per beater
Full powers of beaters with shafting and allowing as much power for running empty on Taylor as Reed	93·15 h.p. per beater = 46·58 h.p. per cwt.	119·15 h.p. per beater = 46·32 h.p. per cwt.

It will be noticed that, although the total power of consumption of the Taylor is in excess of that of the Reed, yet the fact must not be lost sight of that the capacity of the Taylor is in excess of that of the Reed, and the time which the former takes to beat is less. When these allowances are made, and expressed in output per hour, it will be noticed that the Reed beats 225 lbs. per hour, and the Taylor beats 286 lbs. per hour, and that for every ton of stuff the Reed takes 10 hours' consecutive work, and *the Taylor 7 hours* 50 minutes.

Taking the case of the roll down "heavy" with the shafting, the consumption of power per beater comes out at 93·15 for the Reed and 97·6 for the Taylor. If one calculates these figures into horsepower-hours per cwt., the figures for the Taylor are considerably lower.

The figures are not *absolute*, and therefore cannot be used in comparison with other sets, because the whole power to drive shafting, etc., is charged against each set, whereas it should be distributed *pro rata* between them, as already explained. The data is not complete enough to enable this to be done with any great degree of accuracy, therefore I have not attempted it in the above table. We can learn something, however, by taking the first line on Table XXXI.—motor gear (*i.e.* engine) and shafting = 59 h.p. With all work on at 87 revolutions, total power = 455·2 i.h.p.

	I.P.H.
The engine and shafting	59
Balance for driving 6 engines	396·2
	455·2

As 59 is, say, 15 per cent. of 396·5, we should add 15 per cent. to each of the "power per beater" (less total shafting) to arrive at the total power, including its quota of shafting, etc. Thus, if we take the case of the Reed beaters we have $(150{\cdot}7 - 59) = 91{\cdot}7$ for two engines without their shafting, etc. Consequently $\frac{91{\cdot}7}{2}$ = say, 46 h.p. for one Reed engine without its shafting.

$$46{\cdot}0 + \frac{46 \times 15}{100} = 46{\cdot}0 + 6{\cdot}9 = 52{\cdot}9$$

for each Reed engine *with* its due proportion of shafting. So that each Reed engine takes 46 h.p. without shafting, or 52·9 with shafting, because its due proportion of engine (or motor) and shafting takes 6·9 h.p. to drive.

Now, let us take revolution of shaft at 76 instead of 87. The power required to drive empty shafting, etc., may be regarded as having decreased in a similar ratio to the full power, which is now 379·6 instead of 455·2 i.h.p., so that the percentage (15 per cent.) to be added may be regarded as the same. The data is really incomplete because the engine and shafting, with full load, was *indicated* at a different speed to that at which

the trials were conducted, from which the former was calculated thus—

$$\frac{397{\cdot}6 \times 87}{76} = 455{\cdot}2 \text{ i.h.p.}$$

This last figure might be regarded as correct if the horsepower varied *exactly* with the speed, but we all know that this is not so. The horsepower must, therefore, be rather more than the calculated figure, 445·2 ; exactly how much more it is not easy to say. It comes to this, therefore—the figure, 15 per cent., to be added for friction of engine and shafting, if anything, is rather too low, but it is quite near enough for our purpose.

Now, treating the two breakers in a similar manner—

$$(75 - 43) = 31 \text{ h.p. for mean of the two.}$$

$$\frac{31}{2} = \text{say, 8 h.p. for each.}$$

$$8 + \frac{8 \times 15}{100} = 9{\cdot}2 \text{ for each, including shafting ;}$$

so that, whereas gear, shafting, etc., appears at 43 per cent. of the heavy load, because it has to do with shafting for the whole lot of engines, or (75 : 43 : : 100 : 58), say, 58 per cent. as compared with mean load, it really should be only 15 per cent. if apportioned *pro rata* as between the different engines driven by the shafting in question.

Now, let us apply same *modus operandi* with the two Taylor beaters, taking first the—

HEAVY LOAD.

$$195{\cdot}2 - 43{\cdot}0 = 152{\cdot}2.$$

$$\frac{152{\cdot}2}{2} = 76{\cdot}1 \text{ per engine without shafting.}$$

$$76{\cdot}1 + \frac{76{\cdot}1 \times 15}{100} = 87{\cdot}4 \text{ h.p. ;}$$

of which 76·1 is for driving each Taylor and the balance, 11·3, for its shafting, etc.

MEAN LOAD.

$112{\cdot}5 - 43{\cdot}0 = 79{\cdot}5.$

$$\frac{79{\cdot}5}{2} = \text{say, 40 h.p. per beater without shafting.}$$

$$40 + \frac{40 \times 15}{100} = 40 + 6 = 46 \text{ h.p. for each beater "mean"}$$

load with its proportion of shafting.

The question arises, Is the mean load as indicated for tables really a "mean" load?

Possibly the best way to determine this would be to employ an instrument like a dynamometer, which registers any variation in power right through the process, from beginning to end of the beating. From this, as explained early in this volume, the *true* average can be calculated. In any set of trials, the rolls may be put down so as to give, in the beaterman's opinion, the average power consumption, but the judgment of the best of men may be at fault. It would be quite easy, however, to take readings, as with the instruments of an electric motor, when an engine is being got off under quite normal conditions, and when the beaterman himself is not conscious of the fact. There would then be absolutely no bias and no special attempt to "do better" than in ordinary mill practice. If the readings of the electric horse-power were so taken, say, every five minutes, the average over the whole period could be calculated merely by adding up all the readings and dividing these figures by the number of readings.

A further set of tests have been supplied by the same firm who supplied those just described. Unfortunately, it is not possible to discover the composition of the "furnish." This would have added very materially to their value, especially for the purposes of comparison with other tests.

These tests were, however, undertaken with very great care, and, by the aid of information already supplied, in regard to the beaters, breakers, Reeds, Taylors, etc., the various summaries could be prepared from this set of tests by any reader who would care to examine the subject further for himself.

I do not propose to extend the length of this chapter by preparing these summaries. My object has been all along to endeavour to prevail upon readers to form their own conclusions

as far as possible; and if those who are really interested in these records, and have grasped their general principles, care to devote the necessary time, they can obtain some useful summaries from these figures and make comparisons with other tables.

Table XXXIII.

With the mill all on its usual work ...	256 h.p.
With three Reed beaters off	176 h.p.
Showing these three beaters to be taking	80 h.p. (26·6 h.p. each).
With three Reed beaters and three breakers off	66 h.p.
Showing the three breakers to be taking	110 h.p. (36·6 h.p. each).
With three Reed beaters, one small beater and three breakers off ...	60 h.p.
Showing the small beater to be taking	6 h.p.

The tabulated results are as follows :—

No. 1.	256·0 h.p.	—Mill all on.
No. 2.	311·0 h.p.	—Mill all on, rolls hard down.
No. 3.	175·3 h.p.	—Three Reed beaters off.
No. 3A.	176·0 h.p.	— Ditto.
No. 4.	66·4 h.p.	—Three breakers and three Reed beaters off.
No. 5.	61·5 h.p.	—Three breakers, three Reed beaters off, and one small beater off.
No. 6A.	60·0 h.p.	— Ditto.

Note.—In another series given me by the same firm, done on similar lines, the Reed had furnish of 740 lbs. and the beating was done in 2 hours, giving output of 370 lbs. per hour = 1 ton in 6 hours' beating, as against 7 hours 50 minutes for beating 1 ton in the Taylor.

In a similar instance also 195 is the rate of revolution of propeller for Reed beater, and that the rate of circulation is doubled by raising from 195 to 270 revolutions per minute.

With screw propeller at 270 revolutions = 47·4 h.p.
" " " 195 " 31·4 h.p.

The Reed beaters, Table XXXI., rolls have 138 bars, weight 30 cwts.

CHAPTER XIII.

A system of beating combined with a system for continuous bleaching.

THE processes of bleaching and beating are sometimes carried on simultaneously, as, for instance, when rags are bleached in the beater and afterwards "antichlored" before running the stuff into the stuff-chest; or half-stuff may be bleached by special contrivances whilst in agitation and on its way to the beater.

As, however, the processes of bleaching do not *per se* influence, to any material extent, the beating operation, except as a matter of convenience as between the two operations, for a discussion on the subject of bleaching we would refer our readers to the various text-books and published articles devoted to the subject, and confine ourselves to a specific mode of procedure, based upon principles which find favour in some of the newly equipped mills.

In the process about to be described, the stuff, already reduced to the condition of half-stuff, is brought into the Masson bleaching tower C (plan and elevation Fig. 22). This tower is equipped with a slowly revolving drum covered with wire gauze B, driven with a gear-wheel A. The stuff is made to circulate down through the tower in a vertical direction, by means of the circulator, as indicated by the arrows. When the washing is completed the washer drum B removes the residuum of bleached liquor. After which the circulator discharges the contents into one or other of the four Masson tower beaters E. These beaters are somewhat similar to the Taylor beater, only it will be noticed that the stuff passes vertically downwards instead of diagonally. A motor H drives the circulator G. A motor, through the shaft K, operates the beating, circulating, and the discharging of the stuff in the towers.

It will be noticed that the stuff in the Masson tower beaters E, Nos. 1 to 4, is circulated in a similar manner to the stuff in the bleaching towers. The beating is conducted by the rolls F. The mixing of the stuff is promoted by a cone-shaped hood at the

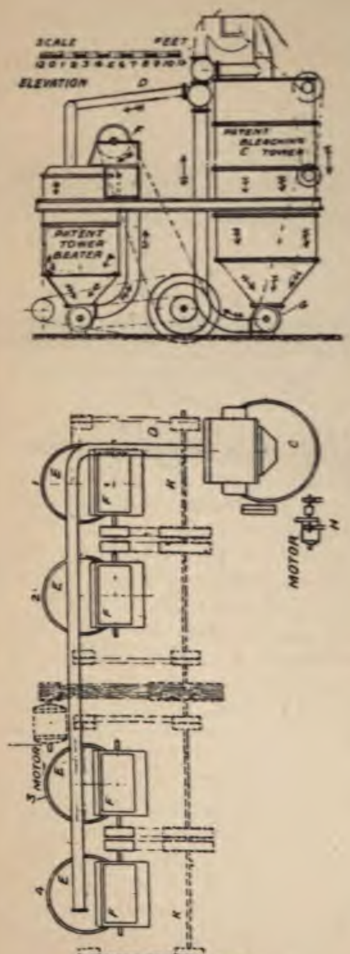

SCALE
FEET
ELEVATION
PATENT BLEACHING C TOWER
PATENT TOWER BEATER
MOTOR
PLAN

FIG. 22.

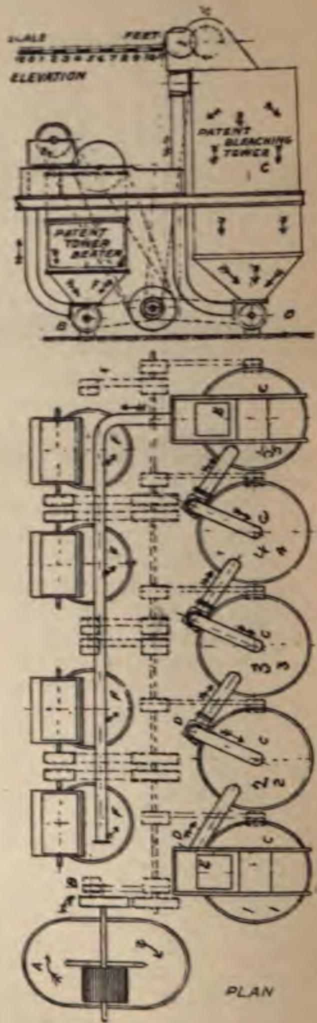

SCALE
FEET
ELEVATION
PATENT BLEACHING TOWER C
PATENT TOWER BEATER
PLAN

FIG. 23.

top of each of the bleaching towers and beaters, which is of such a size as to leave a small annular space through which the stuff has to pass, the stuff discharging on to the top and centre of the cone and sliding down through the annular space between the edge of the cone and tower.

If these operations are to be conducted in as small a space as possible, the plant can be placed as in Fig. 23. Four tower beaters F are each supplied in turn by five bleaching towers C. The installation is suitable for the bleaching of wood-pulp or esparto. The stuff first passes into the large breaking engine A, where, if necessary, it can be washed by a washing drum. To the engine is attached a patent circulator (not shown), which causes the stuff to be discharged into No 1 tower C. Whilst this tower is being filled by repeated charges from the washer, the stuff is concentrated by the washer drum E to about double its former thickness. The stuff in No. 1 tower is now reduced in level so as

FIG. 24.

to stand about 1 ft. from the top, so that the bleaching liquor can be added. Each tower whilst circulating absorbs about 30 h.p. It takes about 5 to 10 minutes to pass the stuff from one tower to another. The stuff is allowed to rest in each of the towers 2, 3, and 4 for about 2 hours, so that in each tower the actual circulation occupies about $\frac{1}{15}$th of the time. It is evident, therefore, that each tower absorbs, on an average, about $\frac{1}{15}$th of 30 h.p. The two outside towers absorb a greater amount of horsepower, because in these the operations of concentration and washing respectively have to be conducted. The circulation in each of these is for a period of 30 minutes out of 150 minutes, or $\frac{1}{5}$th of the time, equal on an average, therefore, to 6 h.p.

The capacity of each of the tower beaters is about 14 cwt. of dry stuff. Each of the bleaching towers has the capacity of about 1000 cubic ft.; five of them being sufficient for the production of about 60 tons of paper per week. The bleaching operation under this system takes about 15 hours. The ordinary concentration of stuff in a Hollander or beater is from 3 to 5 per cent.; in the towers the concentration can be double this.

The process is practically continuous. No. 1 tower is refilled immediately after it is empty, and the material from No. 1 passes to No. 2, from No. 2 to No. 3, etc., and the stuff from No. 5 is continuously being discharged to one or other of the four tower beaters F.

A general view of an existing installation of Taylor beaters and bleaching towers, as seen from the upper floor, is given in Fig. 24.

CHAPTER XIV.

Beaters and Refiners.

The following brief references to beating engines and refiners are added to those already given in the text.

The Umpherston Beater, power trials of which are recorded in Chap. IV., may be regarded as a modification of the Hollander.

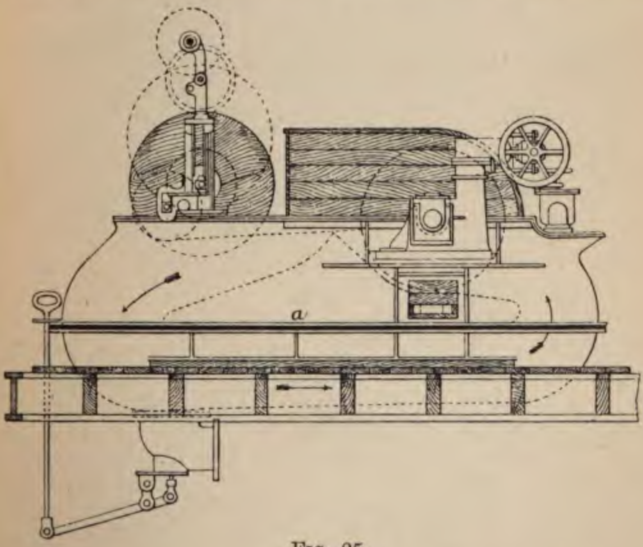


Fig. 25.

The stuff, instead of being made to circulate round in a horizontal position, returns underneath, as shown in vertical section Fig. 25. This engine saves considerably in floor space, and is very much in favour in some of the best-equipped mills.

The Acme Beater (Bertram and Shand's patent) embodies original features in construction and working, of which the more essential are (1) the elevation of the beating roll from the main pulp channel; (2) the provision of a screw propeller for elevating the pulp from the main channel to the roll; and (3) the division of the trough into two channels, the upper of which contains the roll, by a partition which can be made to swing in a practically perpendicular position. This arrangement simplifies the emptying and washing out of the engine. These more important particulars are set out in the annexed Fig. 26, which represents a longitudinal section of the beater.

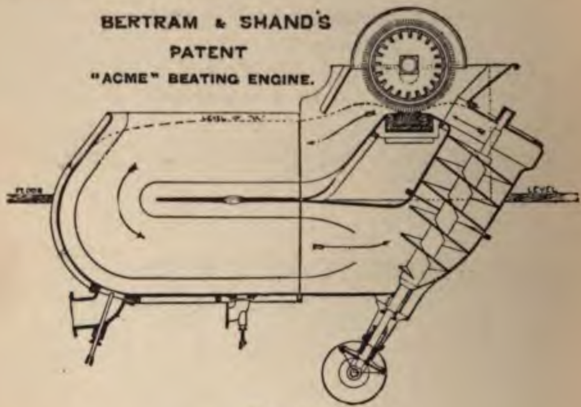


FIG. 26.

The Marshall refiner, to which previous references have been made, as illustrated in Fig. 27, consists of two essential parts: A, a cast-iron cone revolving within the fixed cone A′, fitted with steel angled knives; and B, a cast-iron disc revolving at an adjusted distance from the stationary disc B′, also fitted with angled knives, held in position by hard wood wedges or fillets. The work of the former is to reduce the fibres to uniform length, the disc portion of the engine then reducing the stuff in the plane at right angles; that is, by breaking up fibre aggregates, or even splitting the fibres themselves. Each of these parts having, moreover, a separate adjustment, the work of the engine may be thrown on the one or the other, according to the requirements of the stuff, *and of the* quality of the paper to be made. It is claimed for

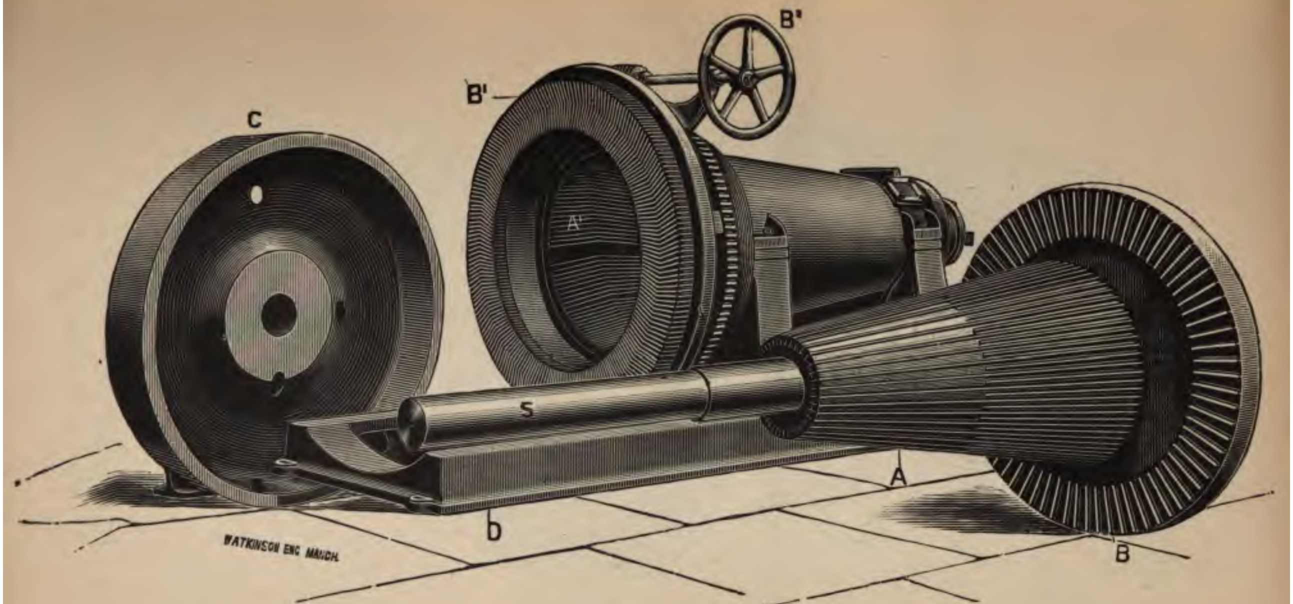


Fig. 27.

this engine that it effects a considerable economy in the tim

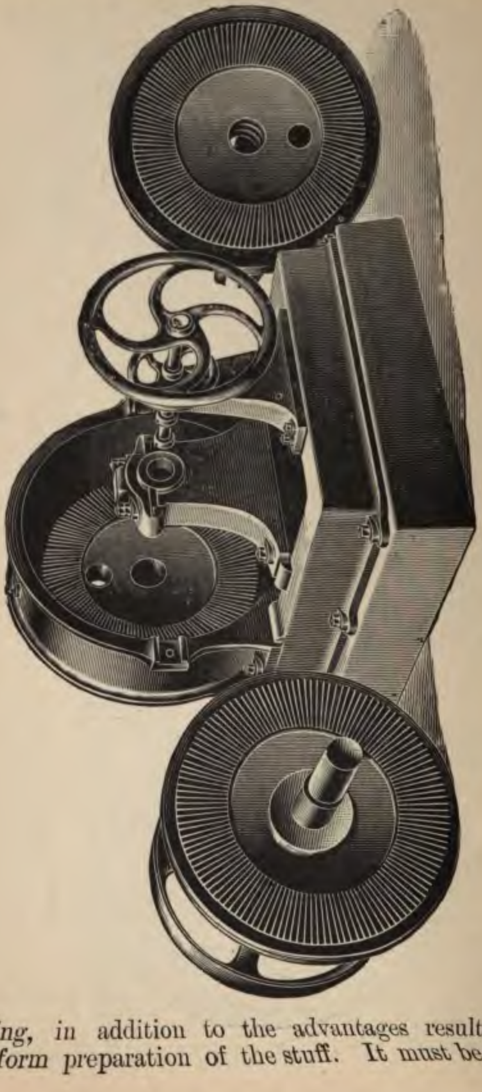


Fig. 28.

of beating, in addition to the advantages resulting from
more uniform preparation of the stuff. It must be remembere

however, that in papermaking, as in the processes incidental to the preparation of textile materials, there are effects which time only can produce, and that, therefore, the refining engine is at the best only capable of substituting the work of the ordinary beating roll within limits.

Fig. 28 illustrates, in elevation, Pearson and Bertram's refiner, made by Messrs. Bertrams, Ltd., and when parts are detached. It consists of a central disc, rotating between two stationary discs. One is securely fixed to the back part of the case, whilst the front one is fixed to a plate, and is adjustable by means of the hand-wheel. The bars, made of bronze, are fitted into dove-tailed grooves in the discs, and are each about 6 ins. long.

The pulp is led through the inlet pipe to the first stationary disc, after which it flows outwards between the front faces towards the outlet pipe in the second stationary disc, the pulp thus passing twice between the bars. Proper reduction and uniformity of stuff is secured owing to the fact that before leaving the refiner it is compelled to pass through the bars against the centrifugal force. This insures that lumps of fibre on entering the bars are immediately thrown outwards again, and prevented from passing through the machine until reduced to smaller particles, when they easily pass against the centrifugal force. For certain fibres this refiner can be arranged with adjustable gear, so that the inner faces can be made to cut the fibres and the outer faces to do the refining proper. In an ordinary sized refiner there are between 500 and 600 bars.

CHAPTER XV.

Power consumed in grinding wood pulp in comparison with that required for beating.

On the assumption that the grinding of wood for the production of mechanical wood pulp may with advantage come within the scope of beating operations, I have included some recent power tests that have been specially supplied for publication in this series.

I am informed that in Germany, where I sought for information on the subject of the difference in the wear of the stones in the grinders for hot and cold grinding, it would be impossible to show a comparison, because only the cold-grinding process is in vogue. The stones vary considerably in size, but the size in general use for grinding is 54 ins. by 27 ins.

The stones used in these trials are supplied by Messrs. Ingvard, Rasmussen & Co., of Newcastle-on-Tyne, who are the shippers of the finest and best qualities of stones for pulp grinding. These stones are all cut from the solid rock in the quarry. It is a well-known fact that Newcastle is especially noted for the production of grindstones for this purpose, there being no less than over 13,203 tons exported from the Tyne to all parts of the globe during 1904.

In the case above mentioned in Germany, which is a fair average one, the stone rotates at 250 revolutions per minute. The wood is pressed against the stone with a pressure of 750 × 1000 grms. per sq. metre. The production of a grindstone in twenty-four hours reaches from 5000 to 5600 kilos of air-dry mechanical prepared for ordinary "news." The power required varies between 280 and 325 German horsepower (P.S.). These figures apply to the production of pulp suitable for printings. Generally speaking, the question of quantity and quality are dependent upon the condition of the wood as to dryness, moisture, hardness, etc.

The German horsepower is not the exact equivalent of the *English*. German horsepower is equal to 75 metre-kilograms per

second. One metre-kilogram = 7·24 ft.-lbs. One German horsepower, therefore, = 75 × 7·24 × 60 = 32,600 ft.-lbs. An English horsepower = 33,000 ft.-lbs., there being a difference, therefore, of a little over 1 per cent. between the two, which can be neglected.

To calculate the average power consumption per cwt., we take the average output ; thus—

$$\frac{5000 + 5600}{2} = 5300 \text{ kilos per day of 24 hours.}$$

The average figure for power consumption is—

$$\frac{325 + 280}{2} = \text{approximately 302 h.p.}$$

$$5300 \text{ kilos} = (5300 \times 2{\cdot}2) = 11{,}660 \text{ lbs. per diem.}$$

This $= \frac{11{,}660}{24}$, or 486 lbs. per hour, which $= \frac{486}{112}$ or 4·34 cwts. per hour.

Now, 4·34 cwts. per hour consumes 302 h.p.-h. (German) ; therefore, the production of 1 cwt. of "mechanical" consumes 70 h.p.-h.

As to the variation in the output of the grinder, from the above figures it is obvious that it varies somewhere between 8 or 9 per cent. above or below the mean figure, according to circumstances. These figures when calculated are equivalent to 735 grams per h.p.-h.* Kirschner gives 700 grams per h.p.-h. as the maximum under favourable circumstances (it is usual to reckon about 500 grams per h.p.-h.). In still more recent (1907) experimental trials with modern machines, he found it took 5 h.p. for 24 hours to produce 100 kgms. air-dry pulp (cold grinding) and 6 h.p. (hot grinding).

From another—a Norwegian—source I have a further set of trials with the same class of stones, and of the same dimensions. The experience in this quarter is that hot grinding wears out the stones much sooner than cold grinding. With hot grinding the stone makes about 200 revolutions per minute, and is somewhat slower with cold grinding, according to the size of the stones used. The size in use for hot grinding is generally 54 ins. by

* For further information on the subject of grinding in Germany, consult "The Paper Mill Chemist," by Dr. H. P. Stevens. Scott, Greenwood & Co., London (pp. 144–5). It will be seen that the results therein recorded from entirely different sources are in close agreement with those quoted by the writer.

27 ins., but the size for cold grinding varies very much. These stones are all cut from the solid rock in the quarry. The wood is pressed by means of hydraulic pressure against the stone in three layers. The pressure is given to me as being about 120 Norwegian pounds per sq. inch; this is equivalent to about 132 lbs. per sq. inch, according to English reckoning, as English pounds are one-tenth less than the Norwegian. The press-stamp is about 10 ins. diameter.

I have the following data in regard to a grinder of this description :—

Power required, 250 h.p.

(There is, of course, extra horsepower required to drive other machinery in connection with the working of the stone, which we have not thought necessary to include in the results.)

Output of dry mechanical per annum is 1100 tons, the year consisting of 300 days' and nights' work.

These are fair figures; all the figures which I put forward can, I feel confident, be relied upon, as I give them upon the best authorities.

Of course, the treatment varies according to the quality of the stone and wood, and largely upon the attention paid to the whole working of the machine. In other words, it depends largely upon the skill of the workman, as also upon the efficiency of the plant and the kind of material under treatment.

Subjecting these figures to the same treatment as the previous set—

1100 tons per annum of 300 days' and nights' work

$$= \frac{(1100 \times 20)}{300 \times 24} = 3{\cdot}06 \text{ cwt. per hour air-dry mechanical.}$$

$3{\cdot}06$ cwt. requires 250 h.p.-h.

$$\text{Therefore, 1 cwt. requires } \frac{250}{3{\cdot}06} = \text{approximately 82 h.p.}$$

Comparing this with the German trials—

	Output, cwt. per hour.	Power consumption h.p.-h. per cwt.
German cold grinding	4·34	70 = 1400 h.p.-h. per ton
Norwegian hot grinding	3·06	82 = 1640 „ „
Mean	3·70	76 = 1520 „ „

It will be noticed that the output in Germany is greater than

in Norway; in all probability this is due to the wood being softer in the former than in the latter country. My inquiries lead me to conclude that this is the cause of the difference, and the fact that the horsepower required per cwt. is less with the German, lends support to this view.

Let us see how these figures compare with those proved for different kinds of raw materials in British paper mills.

With the assistance of the above data, in conjunction with figures given in the earlier part of this volume, the following table is constructed :—

TABLE XXXIV.

	Total power required per cwt. of stuff beating, including the breaking, beating, and refining.
New jute threads	26·34
New linen threads	53·83
Manilla rope	23·36
Sulphite wood	12·52
Above trials for grinding pulp wood to mechanical (mean) ...	76
Preparing mechanical for the paper machine	3 to 4

It will be seen from the above that the amount of power necessary to reduce pulp wood to mechanical pulp is far and away in excess of that required to reduce any other kind of fibre to finished beaten stuff for the manufacture of paper.

On referring to the various trials already published of the power required to reduce mechanical pulp to beaten stuff, it is obvious that this is a very small figure as compared with the amount to reduce the pulp wood to mechanical, say about one-twentieth part. It adds only a few horsepower, and thickening up with wet mechanical is done without the beater feeling it.

CHAPTER XVI.

The reduction in length of fibres at different stages of beating.

THE beaterman is entirely unacquainted with the length of the ultimate fibres, and depends upon one or two practical methods for gauging the amount of beating necessary for the preparation of the stuff to suit the class of paper required. As we have already seen, to gauge whether the roll is down sufficiently hard on the bed-plate, he places his foot on the bed-plate or he merely listens to the sound produced as he lowers the roll. Or he may to some extent judge of the position of the roll as he turns the wheel which lowers the bearings of the roll; the vibration imparted to the beater is communicated to the wheel, and so, by the sense of touch as well as of sound combined with long practice and a knowledge of the material that he is operating upon, together with, perhaps, a knowledge of the condition of the beater-bars and bed-plate at the time, and such commonplace data, he is able to form a very shrewd opinion. By pressing with his wooden clog on the metallic ring of the bed-plate he gets some considerable idea as he lowers the roll; but, better still, by placing a pole or stick of hard wood from three to four feet long with one end against the bed-plate and the other in contact with his ear, he has a more sensitive knowledge of the position of the roll. At times the roll is made to rest with the whole of its weight upon the bed-plate, which the beaterman can usually see for himself to be the case by looking at the bearings; in such cases, if there is no top bearing, the pressure is at its maximum. In some beaters (a point already referred to), there is a rough dial or indicator which shows exactly where the roll is in relation to the bed-plate, and this is a very fair guide to the beaterman. The contact line of the indicator must, of course, be adjusted from time to time as the bars wear away.

In the breaker in the case of rags, etc., their condition is judged by their appearance. When sufficiently reduced to constitute *half-stuff* the material is emptied into the beater. As has

already been pointed out, the extent of the reduction in the breaker depends upon the requirements of the mill, and is entirely arbitrary.

Changes take place in the appearance of the stuff on its travel round the beater during the process of beating, particularly with rags. In the early stages the circulation is extremely sluggish and the stuff retains the appearance of half-stuff. As the beating proceeds the circulation gradually improves, and the great clotted masses break, showing lines of cleavage as the stuff turns the corner become less apparent.

The paddle used for removing lodgments, if passed through the stuff in the early stages, takes hold of the stuff or mass or pushes it aside in lumps, and as the beating proceeds a pole drawn through the stuff and lifted out horizontally, holds the stuff on the surface like so much snow. As the stuff gets finer a wire drawn through it, noting how the material clings to the wire, serves to give some rough idea of the length of the fibre.

Towards the close of the beating—that is with fine papers—a more refined method than any of the foregoing is needed. It is advisable to adopt the hand-bowl method. This is usually employed as follows: Two hand-bowls, preferably made of rubber, as supplied by the North British Rubber Co., are taken one in each hand, and, with the right hand, the hand-bowl is made to skim the surface of the stuff at different points, so as to accumulate a small and average sample consisting of an ounce or two of the stuff. The left hand-bowl is filled with water and the water poured from one hand-bowl to the other, so as to distribute the stuff in the water. Half is now poured away, filled up with water, and again poured backwards and forwards. Again half is poured away, and so on, until the stuff is sufficiently attenuated to show the individual fibres floating separately in the water. The stuff is now poured slowly over the lip of one hand-bowl to the other, the beaterman critically examining it all the time. If the stuff is not cleared, *i.e.* if the fibres are still adhering to one another, or if the stuff is in knots, these can readily be seen. Furthermore, the beaterman can take a mental note of the exact length of the stuff, and so ascertain whether it has been reduced to the length required for the machineman. If the stuff is now short enough but not clear, the roll is raised until the stuff is cleared.

Although such methods as these are, perhaps, all that is required for the beaterman; in discussing the theory of the subject, it is important that we should have some knowledge of the actual length of the fibres during the different stages of the beating.

We have gone to some considerable trouble to ascertain this by means of the microscope.*

As very little work has been done in the direction of measuring the actual length of the fibres during the process of beating in preparation of pulp for the manufacture of paper, the arrangements were made with a well-known firm of papermakers to withdraw samples of pulp from the Hollanders during the beating operation. These Hollanders were of the ordinary type and of about 3 cwt. capacity. These samples were withdrawn whilst the beaterman manipulated the roll in the ordinary way for the manufacture of the paper that he had to provide for. In this manner, in the work about to be described, samples of pulp were taken every hour. There was no attempt to determine the length of the fibre at the commencement of the beating, as when the fibres are in the condition of rag "half-stuff" it is almost impossible to arrive at even an approximate estimate by means of measurements under the microscope. It might be assumed, however, that the cotton and linen fibres as "half-stuff" are intact, and therefore an average length of each, based on published figures, may be taken as representing the length of the fibres as half-stuff. As, however, such a figure is a pure assumption, the length of fibre is given in tables and curves as from the end of the first hour in each case. Furthermore, measurements made at an earlier stage in the beating would have little practical value.

TABLE XXXV.

Details of Measurements of Linens after Nine Hours' Beating.

	Length Mm.	Length Mm.
	2·92	1·87
	2·64	3·82
	2·43	2·22
	2·50	1·74
	2·16	2·92
	2·71	2·82
	2·85	2·78
	1·81	2·78
	3·61	3·61
	3·82	3·40
Mean ...	2·74	2·80

* "Diminution in the Length of Cotton and Linen Fibres during the Preparation of Stuff for the Manufacture of Paper." Clayton Beadle and Henry P. Stevens, CHEMICAL NEWS, September 20, 1907.

Mean length of foregoing twenty readings		2·77 mm.
„ diameter of first ten readings	...	0·0187
„ „ second ten readings	...	0·0181
„ „ twenty readings	...	0·0184

TABLE XXXVI.

Examination of Linen Pulp at different stages of the Beating for Length of Fibre. (See Curve A, Fig. 29.)

(Beaten for 30 lbs. 21″ × 33″).

Hours of beating.	Average length. Mm.	Average diameter. Mm.
1	13·3	0·0222
2	9·4	0·0227
3	5·62	0·0260
4	4·37	0·025
5	3·92	0·023
6	3·37	0·021
7	3·58	0·020
8	2·89	0·0185
9	2·77	0·0184
(*a*) 10	2·14	0·023

(*a*) Taken on fibres from finished paper.

TABLE XXXVII.

Linens Beaten for Five Hours at different stages of the Beating.

(See Curve B, Fig. 29.)

Hours of beating.	Average length. Mm.	Average diameter. Mm.
1	6·34	0·0177
2	2·84	0·0190
3	1·82	0·0186
4	1·94	0·0174
5	1·70	0·0199

TABLE XXXVIII.

Cotton ("Scotch Fines") at different stages of the Beating. (See Curve C.)

(Beaten for 100 lbs. Imperial.)

Hours of beating.	Average length. Mm.	Average diameter. Mm.
1	3·59	0·0185
2	3·40	0·0180
3	2·34	0·0208
4	2·26	0·0184
5	2·02	0·0181

With very long stuff, or stuff that has been very little beaten, it is extremely difficult to arrive at the average length, because it requires a great deal of experience to obtain on the "field" a representative set of fibres, many of them being in the form of threads or small woven particles. When, however, the work of unravelling the threads is accomplished, the measurement can be more easily made. Where possible, two sets of readings were taken of each sample, each set consisting of ten determinations for length and diameter. The measurements were made under a magnification of seventy-two diameters. The average of each set should bear a fairly close correspondence with one another, and each set should be the result of measurements of different "fields." As indicating the extent to which the individual fibres varied in length, we give in Table XXXV. details of measurements after nine hours. In Table XXXVI. we give a summary of this trial on linens beaten for ten hours. Tables XXXVII. and XXXVIII. are summaries of similar trials.

It will be noticed that, in the case of Table XXXVI., there is, with one or two exceptions, a decrease in length of the fibre from hour to hour. The same will be noticed in respect to Tables XXXVII. and XXXVIII. Where the fibres showed any marked irregularities, the work was carefully repeated, and it was finally found that, in the case of the linens, a diminution in length could be represented by Curves A and B.

In the case of the cottons (Curve C, Fig. 29) the diminution is apparently somewhat spasmodic, the result possibly of a sudden lowering of the beating roll. It will be noticed that, in the curves

A and B, during the first two hours there is a very great diminution in length, but during the second half of the beating the length is only influenced to a comparatively small extent. No doubt, had we been able to take the actual length of the fibres before the beating commenced, we should have found possibly as much diminution during the first hour's beating as was to be noted in the other nine hours. Such curves have, as far as we are aware, never before been constructed.

We consider it quite unnecessary to give detailed information in

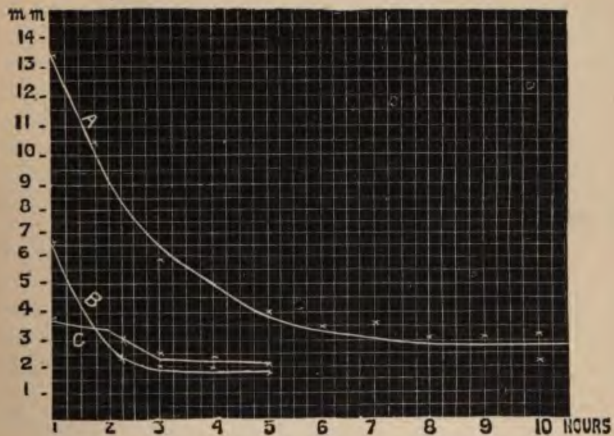


FIG. 29.—Curves showing the diminution in length of cotton and linen fibres during the process of beating from rags.

regard to individual measurements beyond those already given, because these details would run into many pages of tabular matter. One other point of interest arises apart from the average length of the fibre during the period of the beating, namely, the degree of uniformity. Some idea of this can be got by taking the individual figures of the different sets of measurements, selecting the longest and the shortest, that is to ascertain the maximum and minimum. In the case, for instance, of those measurements made for Table XXXVIII., the maximum after the first hour's beating was 5·9 mm., the minimum 2·2 mm. Now, if we take the mean of these two figures, we shall get the figure 4·05 mm. In the second lot of measurements the maximum is

9·6 mm. and the minimum 2·3 mm., the mean of which is 5·1 mm., whereas the mean of the whole lot of measurements is 3·59 mm. The fact, as in the cases cited, that the actual mean is considerably lower than the mean of the maximum and minimum, makes it evident that there is not an equal number of fibres of different sizes, but that there are a greater number of comparatively small fibres than large ones. This is what we might expect during the early stages of the beating, namely, that certain fibres are already cut asunder, whereas some few have practically escaped.

The relative lengths of fibres, that is the comparison of the lengths of individual fibres apart from their actual or mean lengths, is, in the author's opinion, a useful study in connection with the subject of beating. This subject appears to have received no attention until the authors of these researches took the matter up as a systematic study. Now, we have many thousands of measurements of the length of fibres for the purpose of recording their average length. This has been done by taking paper and also pulps during the different stages of beating in the manner above shown.

TABLE XXXIX.

	A	B	C	D	E	F
	1	1	1	1	1	1
	1	1	1	2	2	2
	1	1	2	2	3	3
	1	2	2	3	4	4
	1	2	3	4	5	5
	1	2	3	5	5	6
	7	7	7	7	7	7
	13	16	19	24	27	28
Mean (Y)	1·86	2·28	2·73	3·44	3·86	4·00
$\frac{\text{Max.} + \text{min.}}{2}$ (X)	4·00	4·00	4·00	4·00	4·00	4·00
$\frac{X}{Y}$	2·15	1·75	1·47	1·16	1·04	1·00

The above hypothetical Table XXXIX. is merely constructed to represent the *relative* lengths of fibres when the maximum and minimum lengths bear a definite ratio to one another, in this case as 7 is to 1. In the case of A we have a number of small fibres in admixture with one large one, in the case of B we have three *dimensions, in* C four dimensions, in D six dimensions, in E six

dimensions, in F seven dimensions. Now, in comparing these columns, it will be noticed that the figure against *real* mean is of an ascending order from A to F. If, however, we take the mean of the maximum and minimum lengths the figure is, of course, the same in each case. The relationship of one to the other is expressed in the last row, in which it will be seen that the ratio as represented under A is 2·15, and reaches unity under column F. Now, if we similarly work out the value of $\frac{X}{Y}$ in cases where measurements are made at the different stages of beating, we find the following values :—

TABLE XL.

Hours.	$\frac{X}{Y}$	Hours.	$\frac{X}{Y}$
1	1·12	1	1·67
2	1·15	2	1·13
3	0·98	3	0·98
4	1·10	4	1·16
5	1·26	5	1·01
6	1·02	6	1·38
		7	1·09

It appears, from the above table, that what disparity there is between the two means X and Y at the beginning of the beating, as well as in the middle, the same disappears at the end of the beating, so that the fibres in question are found to be in order of relative lengths as per column F, Table XXXIX., and consequently $\frac{X}{Y}$ approximates to 1·0.

Taking now, in a similar manner, figures at the close of the beating operation, as in the case of the two columns of Table XXXV., the figures are found to be as follows for linen, after nine hours' beating :—

TABLE XLI.

	First set.	Second set.	Mean of both sets.
Maximum length	3·82	3·82	3·82
Minimum length	1·81	1·74	1·77
Mean of maximum and minimum	2·81	2·78	2·795
Mean *of all in the* measurements	2·74	2·80	2·77

It will be seen from the above that the actual mean is midway between the maximum and minimum length, instead of, as at the beginning of the beating operations, being much nearer to the minimum length. This would indicate that when the beating operation is completed there are an equal number of fibres whose lengths range themselves on either side of the mean, consequently $\frac{X}{Y} = 1{\cdot}0$.

And it is interesting to see how far this is so in the case of *paper* similarly examined, care being taken that in the process of reducing the paper to pulp for examination under the microscope, the fibres are not further reduced in length.

In the case cited, the ratio of X to Y is, after first hour, 1·67; at the end of the second hour the ratio has become 1·13; the third hour, 0·98; the fourth hour, 1·16. In other words, the disparity between the two means X and Y disappears at some time during the beating. If from this stage the roll is suddenly lowered for a limited period, some of the fibres would be still further reduced in length, whereas others would remain untouched. This might again result in a disparity between X and Y as above mentioned, until equilibrium had again been established by extended beating.

It would follow, therefore, that with normal beaten stuff, where fibres are represented in length by ten dimensions; for every 1000 fibres there would be 100 each of lengths 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, respectively.

This is a point, however, of more or less theoretical importance, but it has some bearings upon the question of the structure of papers; and let it be understood that the structure of papers, their physical qualities, etc., depends not only upon the average length of the fibres, but also upon the variation in the length of individual fibres which it contains. This is a point which is only briefly referred to here, but is more particularly dealt with elsewhere.

In passing, it might be said that when a paper is taken and tested for the average length of fibre, the ratio of the individual lengths of fibres do not necessarily show the relationship with one another as in the case of stuff taken out of the beater from one particular kind of pulp, as a paper generally consists of a number of beaten pulps blended together either in the engine or in the chest.

The curves, Fig. 29, show that beating does not only consist in the reduction of the length of the fibre, as if such were the case, taking the case of the curve C, the beating would have been finished

in three hours instead of five; and in the case of curve A, eight hours instead of ten. However, further prolongation of the beating is needed partly to give the stuff the necessary degree of wetness and felting qualities, and partly to clear the fibres as already mentioned. One also learns an important lesson, namely, that if the amount of beating is recorded from the view merely of the reduction of the fibre, as for example taking the case where beating has to be prolonged for ten hours, more than half the beating would be said to have been accomplished during the first hour, and perhaps 95 per cent. at the sixth hour, and 100 per cent. of it at the eighth hour. It is obvious, therefore, that whilst the fibres are still long the beater bars are very active in reducing the length, but when the reduction has proceeded to a certain point the effect is comparatively slow—that is, if merely judged from the reduction in *length* point of view.

Let it be also remembered that, in the case of such materials as hemp, side by side with the reduction in length there also proceeds a reduction in diameter due to the longitudinal subdivision or splitting-up of the fibres into smaller particles; this, of course, entails expenditure of power. Fibres such as cotton are, as will be seen, little affected in diameter during the process of reduction, although perhaps much distorted and bruised.

Whilst on this subject we give abstracts of figures obtained by Hubner in a model beater, both for cotton and wool.*

TABLE XLII.

Cotton.		Wool.	
Time of Beating. Hours.	Average length of fibre in mm.	Time of Beating. Hours.	Average length of fibre in mm.
0	23·0	0	29·0
1·5	2·5	1·5	3·12
3	1·5	3	2·2
4·5	1·1	4·5	0·7
6	0·7	6	0·4

The ultimate fibres of those materials used in the manufacture of the very best classes of papers, notably cotton, linen, hemp, ramie, manilla, etc., are under ordinary circumstances reduced in length in the process of manufacture, however carefully the material is manipulated with the object of preserving the length of the fibre. From a careful investigation of this subject, by taking measurements of the length of the fibres at different stages of

* "Journal of the Chemical Society," vol. xci. p. 1059.

the beating, as in the case of flax, hemp, cotton, and linen rags, we were led to conclude that it is impossible to preserve the ultimate length of the fibre; thus, in the case of flax fibre, for instance, as used in the manufacture of the strongest papers now produced, each ultimate fibre is reduced by being cut into at least four or five pieces before being reduced to the condition of pulp. This, moreover, is the prevailing opinion and experience of practical papermakers, but it has hitherto lacked evidence in the shape of actual measurements under the microscope.* We have, however, recently discovered that under certain conditions the cotton fibre can be reduced to pulp with little or no reduction in the initial length of the ultimate fibre.

For the purposes of this investigation a short-fibred cotton was selected, the cotton chosen being that which is partially removed by delinters from cotton-seed after the ginning operation.† This fibre was boiled under pressure in a Jena breaker placed in a digester, the conditions of the boiling being varied to determine the most favourable conditions for the production of a product available for papermaking. The results of these digester trials are summarized in Table XLIII. The time taken to reach the pressure mentioned on the table is about one hour. The time of boiling is reckoned from the time the recorded pressure is reached. The percentage of soda on the weight of the fibre, as well as the strength of the soda solution, is stated in the table.

After blowing off and discharging from the boiler, the product was in each case thoroughly washed on a wire sieve and then mixed with a solution of bleaching powder equal to twenty times the weight of the fibre, and left until a good white colour was produced. The product was then thoroughly washed, carefully bone-dried, and, after sufficient exposure to the air, was weighed in its air-dry form, from which weight the percentage yield was calculated. The yield was found to vary between 80 and 66 per cent., according to the quality of the raw fibre, and the air-dry moisture of the bleached product to be about 7 per cent. The air-dry bleach fibre was extracted for four hours with ether in a Soxhlet and subsequently for four hours with alcohol, the results of which tests are recorded in Table XLIII., together with the percentage of ash found in the bleach product.

* "An Investigation to determine the Papermaking Qualities of Short Cotton Fibres." Clayton Beadle and Henry P. Stevens, CHEMICAL NEWS, April 19, 1907.

† The product of the Bremer Baumwoll-Werke of Hemelingen, near *Bremen*, the preparation of which the author has made a study of.

TABLE XLIII.—*Summary of Boiling Trials.*

No.	Date.	Amount taken, air-dry.	Pressure.	Time.	NaOH on fibre.	NaOH on solution.	Bleach on fibre.	Yield of bleached half-stuff, air-dry.	Ether extract.	Alcoholic extract.	Total extract.	Ash.
		grms.	lbs.	hrs.	p. ct.	p. ct.	p. ct.	p. ct.	p. ct.	p. ct.	p. ct.	p. ct.
1	5/12/06	100	15	4	8	1	2·5	—	0·17 (*a*)	0·53 (*b*)	0·7	0·5
2	—	100	15	4	8	1	2·5	—	0·22 (*a*)	0·54 (*b*)	0·76	—
3	—	195	{15 56	1 3}	10	2	2·5	—	0·11 (*b*)	0·50 (*a*)	0·61	0·48
4	12/2/07	300	{15 56	1 3}	10	2	2·5	67 0	0·116 (*a*)	0·41 (*b*)	0·526	0·24
5	13/2/07	300	45	4	10	2	2·5	68·0 }	0·15 (*c*)	—	—	0·4
6	14/2/07	300	45	4	10	2	2·5	70 0 }	0·126 (*d*)	—	—	0·4
7	15/2/07	300	45	4	10	2	5·0	— }	—	—	—	—
8	18/2/07	300	45	4	10	2	5·0	66·3	—	—	—	—

(*a*) First extraction. (*b*) Second extraction. (*c*) Paper A. (*d*) Paper B.

TABLE XLIV.—*Lengths of Fibres.*

	Boiled and bleached cotton, before beating.			Paper A.			Paper B.		
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
	3·6	0·9	1·2	2·9	1·4	2·4	3·1	1·7	2·4
	1·7	2·1	1·9	1·4	1·7	2·1	1·2	1·7	4·0
	0·9	2·4	4·3	2·4	1·2	1·2	1·2	1·7	0·9
	2·1	2·1	3·8	3·8	3·1	2·9	0·9	1·9	0·5
	1·7	1·9	1·9	2·9	1·4	4·8	2·9	2·1	1·0
	3·1	2·1	2·6	1·4	1·4	1·7	1·4	4·0	1·7
	1·9	5·0	5·0	4·3	2·1	2·6	1·0	2·1	1·7
	4·3	0·7	0·7	1·0	2·4	0·9	0·9	1·7	0·7
	2·9	1·4	2·4	1·2	1·0	2·4	1·2	0·9	0·3
	1·0	1·4	1·4	0·7	1·7	2·6	1·2	3·3	4·0
	4·5	3·3	0·7	4·8	2·4	0·7	1·0	1·0	1·2
	1·2	4·5	1·9	3·6	3·8	1·7	3·3	1·4	0·7
	3·1	0·5	3·6	0·7	3·1	3·6	2·4	0·7	0·9
	1·4	2·1	1·0	1·2	1·7	1·9	1·9	0·5	1·0
	1·2	3·2	0·5	3·1	2·4	1·2	2·1	1·4	1·7
Mean	2·31	2·25	2·19	2·36	2·05	2·28	1·71	1·74	1·51
Mean of three columns =	2·25			2·20			1·65		

The product from boilings 5, 6, and 7, after thorough mixing, was beaten in a small Hollander of 200 grms. capacity and converted into paper. The first lot (A) was beaten with the object of conserving the length of the fibre as far as possible; the second lot (B) was beaten so as to somewhat reduce the length of the fibre.

The beating of A was started at 11 a.m. with the "roll" off the plate; the roll was lowered just to brush the fibres at 11.30 a.m.; at noon, when the noise of "brushing" had disappeared, the roll was further lowered so as to "brush" again, and left until (at 1 p.m.) fibres were completely separated. Total time in beater was two hours.

The beating of B was started at 2.10 p.m. with roll just brushing; the roll was further lowered (at 3.10 p.m.) so as to brush harder; at 3.30 p.m. the roll was further lowered, so as to just touch the plate and reduce length of fibres; and at 4 p.m. was further lowered, so as to beat harder, and so left until finished at 4.10 p.m. Total time in beater was two hours.

The beaten stuff A was run off on a miniature paper machine, made by T. J. Marshall & Co., this is a complete Fourdrinier paper machine. The behaviour of the stuff was very carefully watched. The stuff worked very "free" on the machine, *i.e.* it parted very readily with its water, as a paper would do in the manufacture of blottings.

In the case of B, when run on the paper machine it was observed that the pulp worked sufficiently "wet" for all ordinary purposes of manufacture, and held the water up to the "dandy," so that the fibres could be well knitted together by the shake of the paper machine. Both papers looked well.

An average sample of the cotton fibre before beating was carefully secured from different parts of the bulk and intimately mixed. A number of fields were examined under the microscope, from which measurements of length were made, as shown in the first three columns of Table XLIV.

Papers A and B were carefully reduced to the condition of pulp without reducing the length of fibre, and similarly mounted for measurement under the microscope, the results of which are also given on Table XLIV.

Each set of measurements consists of three columns of fifteen measurements each. The average of each column differs only slightly. At the bottom of the table is given the figure for the forty-five readings recorded in each set.

Table XLV., which is prepared from above averages, shows that the reduction of length by beating in the case of A is practically

Table XLV.

	Mean lengths of fibre from 45 readings.	Reduction in length of fibre on beating.	Calculated number of fibres cut during beating.
		per cent.	
Boiled and bleached cotton, before beating	2·25	—	—
Boiled and bleached cotton, when beaten for Paper A	2·20	2·2	1 in 23
Boiled and bleached cotton, when beaten for Paper B	1·65	26·6	1 in 3

Table XLVI.

1	2	3	4	5	6	7	8	9	10	11	12
Reference No. of sample, etc.	Air-dry weight of water-leaf.	Wet weight after dipping in 5 per cent. gelatin solution.	Weight of 5 per cent. gelatin solution taken up by the water-leaf.	Air-dry weight of gelatin taken up by paper.	Air-dry weight of paper after sizing with gelatin.	Percentage of air-dry gelatin calculated on air-dry weight of sized paper.	Thickness (in mm.) of paper from average of five thicknesses, measured with fraction micrometer.	Mean strength of paper after sizing, being the result of two tests in each direction of the web.	Mean strength, corrected to 0·1 mm. thickness.	The additional strength due to sizing with gelatin (expressed on sheets 0·10 mm. thickness).	Increase in strength due to gelatin after deducting the strength due to water-leaf and reducing to strength per each 1 per cent. gelatin on paper 0·10 mm. thickness.
						per cent.	mm.	lbs.	lbs.	lbs.	lbs.
Sample A. 1 ...	1·05	3·17	2·12	0·106	1·156	9·2	0·096	15·92	16·58	9·11	0·99
,, 2 ...	1·07	3·05	1·98	0·099	1·169	8·5					
,, 3 ...	0·92	1·61	0·69	0·0345	0·9545	3·7	0·084	10·35	12·32	4·88	1·32
,, 4 ...	1·07	2·07	1·00	0·050	1·120	4·5					
,, 5 ...	1·06										
Sample B. 1 ...	1·00	1·69	0·69	0·0345	1·0345	3·3					
,, 2 ...	1·17										
,, 3 ...	1·20	2·23	1·03	0·0515	1·2515	4·1					
,, 4 ...	1·32	1·86	0·54	0·027	1·347	2·0					
,, 5 ...	1·26	2·10	0·84	0·042	1·302	6·4	0·084	15·30	18·59	6·59	1·03

nil, and in the case of B only about 27 per cent. From these figures it is evident that, in the case of paper A, only 1 fibre in 23 is cut by the beater knives; and, in the case of B, about 1 in each 3 fibres. Contrast this with the beating of ordinary cotton and linen rags for the production of "long stuff," where each fibre is cut on an average into five or ten pieces. These results prove to our satisfaction that such short-fibred cotton can be reduced to the condition of pulp without reducing the length of the fibres; or, in other words, the ultimate fibres can be separated from one another and suspended in their watery medium for conversion into paper without being cut asunder. This, however, has never in our judgment been done in conversion of long-fibred waste cotton into beaten stuff, nor is it possible to do so in the conversion of cotton rags into pulp, because, during the process of unravelling the latter or of undoing the work of the spinning and weaving operations to secure the suspension of the individual ultimate fibres in their watery medium, it is impossible to avoid the cutting asunder of the ultimate fibres into several individual pieces. It is noteworthy that, by careful brushing in the beater, and by avoiding the beating operation proper, and by using short-fibred cotton in the manner above described, paper can be produced consisting of intact ultimate cotton fibres of such length that they are suited to the work of the papermaker. We regarded it of interest to examine such paper for physical qualities.

Accordingly, unsized paper from papers A and B were submitted to physical tests for strength, with the results as follows:—

Unsized paper A and B—

	A	B
Mean strength of machine direction (lbs.) ...	9·0	10·0
Mean strength of cross direction (lbs.) ...	3·5	6·25
Mean of both directions	6·25	8·12

Mean thickness of five sheets ... ... $\begin{cases} A = 0·084 \text{ mm.} \\ B = 0·074 \text{ ,,} \end{cases}$

Mean strength of each paper corrected to 0·1 mm. thickness $\begin{cases} A = \dfrac{6·25 \times 0·100}{0·084} = 7·4 \text{ lbs.} \\ B = \dfrac{8·12 \times 0·100}{0·074} = 11·0 \text{ ,,} \end{cases}$

Five sheets of A and B were impregnated with a 5 per cent. *solution of* gelatin at 110° F., containing a small amount of alum,

ınd passed between squeezing rollers to squeeze out the excess ınd hung up to air-dry, after the manner employed for tub-sizing n the papermill; the sheets were weighed immediately before ınd after sizing, from which the amount of gelatin, as retained by the air-dry paper, was calculated.

Certain of these sheets—A1, A3, and B5—were tested for trength, total stretch, and permanent stretch, with the results as ollow :—

Sized paper A1 tested for strength as follows :—

	Machine direction. lbs.		Cross direction. lbs.
1	19·6	3	12·0
2	19·5	4	12·6
Mean ...	19·55		12·3

Iean of the two directions ... ... = 15·92 lbs.
ıverage thickness of five sheets ... ... = 0·096 mm.
Iean strength per 0·10 mm. of thickness ... = 16·58 lbs.

Sized paper A3 tested for strength, total stretch, and ermanent stretch as follows :—

		Strength. lbs.	Total stretch. per cent.	Permanent stretch. per cent.
Machine direction ...	1	13·7	7·6	3·0
	2	14·3	8·4	4·0
Mean		14·0	8·0	3·5
Cross direction ...	3	6·3	7·2	3·8
	4	7·1	9·4	5·0
Mean		6·7	8·3	4·4
Mean of both directions		10·35	8·15	3·95

.verage thickness of five sheets ... ... 0·084 mm.
.verage strength of both directions of sheet per 0·10 mm. thickness ... ... 12·32 lbs.

Sized *paper B5 tested* as follows :—

		Strength. lbs.	Total stretch. per cent.	Permanent stretch. per cent.
Machine direction ...	1	18·2	8·0	4·2
	2	16·7	9·4	4·6
Mean		17·45	8·7	4·4
Cross direction ...	3	12·4	12·0	6·0
	4	11·8	11·6	5·2
Mean		12·1	11·8	5·6
Mean of both directions		14·77	10·25	5·0
Average thickness of five sheets				0·084 mm.
Mean strength per 0·01 mm. thickness				17·59 lbs.

For purposes of comparison, the strength is finally expressed on paper of 0·1 mm. thickness and 25 mm. wide. Tests on the water-leaf papers as summarized in Table XLIV., show that paper with the short fibre has the greater factor of strength, due no doubt to the fact that the hydration of the fibre from the extra beating has increased its felting qualities. Here we have an exemplification of the apparent anomaly of increase in strength accompanying decrease in ultimate length of fibres. Column 10 gives some idea of the relative strengths of these papers, and goes to show that, in the case of B, although the ultimate fibre is reduced in length, yet it gives a greater breaking strain than unreduced fibre A3 for papers of the same thickness; and, furthermore, in the case of A1 and A3 (Columns 8 to 10), it appears that a paper of greater thickness gives a greater factor of strength.

The latter confirms the observations made by one of us as applied to papers consisting of pure linen, namely, that the greatest factor of strength is not obtained on the thinnest papers, but on fairly thick papers.* Furthermore it will be noticed (Column 12) that the influence of gelatin sizing is to increase the factor of strength per unit of added gelatin in an inverse ratio to the amount of gelatin. This confirms our previous observations that such is the case provided the amount of gelatin added is not too small.*

* Beadle, "The Fibrous Constituents of Paper," TECHNICS, vol. ii, *p.* 254.

† *Beadle* and Stevens, "The Influence of Sizing upon the Strength of *Papers*," JOURN. SOC. CHEM. INDUSTRY, vol. xxiv. p. 775.

PHOTOMICROGRAPHS OF PAPERMAKING FIBRES.

Hemp fibres unbeaten.

Radial section of spruce wood × 325.

Cotton fibres (transverse sections) × 325.

Straw pulp.

Hemp fibres when beaten.

To face page 162.]

PHOTOMICROGRAPHS OF PAPERMAKING FIBRES.

Chemical wood fibres (pine or spruce) × 150.

Wheat straw (transverse section) × 30.

Tangential section of spruce wood × 325.

Chemical wood pulp fibres × 150.

Straw pulp washings × 325.

Straw pulp washings from drum washer.

To face page 163.]

The investigation is a somewhat difficult one, and requires further research on these points, but it goes to show without doubt that, with short-fibred virgin cotton, consisting largely of fibres without collapsed walls and twists, and no central canal, excellent papers can be produced with little or no reduction in ultimate length of the fibres, and that such papers give a fair strength, equal at least to those from ordinary rags, and that the gaining in strength due to the sizing of gelatin is very marked. Furthermore, it shows that if such fibres are somewhat reduced in length by the beating, they behave on the Fourdrinier machine like those prepared from rags, and possess excellent felting qualities; in fact, the paper produced from such a material is, in our opinion, as good in texture, appearance, and other qualities as that produced from cotton rags as used in the manufacture of high quality rag-papers.

The photomicrographs on plates facing pp. 162 and 163 serve to give the reader some idea of the natural appearance of some of the papermaking fibres when viewed under the microscope. The condition of hemp fibres before and after beating is to be noted, as also the transverse section of cotton, the different appearances of chemical wood fibres and straw pulp, etc. As the subject of the microscopic features of papermaking fibres does not properly come under treatment in this book, readers are referred to text-books on papermaking. For the most extensive series of photomicrographs the reader should consult those appearing in "The Fibrous Constituents of Paper," as published in TECHNICS, George Newnes, Ltd., London, and the PAPERMAKER, S. Chas. Phillips & Co., London, upwards of 100 having already appeared.

CHAPTER XVII.

Methods for determining the "wetness" of beaten stuff.

When beaten stuff ready for the paper-machine is sufficiently diluted with water, say, to a solution containing $\frac{1}{2}$ per cent. of dry weight of fibres, is placed in a tall jar and allowed to settle, it will be observed that the longest and thickest fibres tend to settle first, then the fibres of intermediate size, and finally the finest fibres, so that the settled stuff is disposed, to a certain extent, in layers with the larger fibres at the bottom, and the smallest or shortest at the top. In the matter of settlement from a watery medium, fibres to some extent obey well-known laws, which have been studied in connection with the settlement of small crystals, clay, and gritty matter from water.

This rate of settlement, as well as the closeness of the sediment, is affected by the temperature of the water. With pulps of a mixed character, in particular, one has not only to contend with different lengths, but also with different diameters of fibres, such as in mixtures of chemical wood and straw or esparto. The rate of settlement is affected both by the diameter and length of the fibres. It furthermore is affected by the specific gravity of the fibres, and as the apparent specific gravity of any one fibre, such as the cotton fibre, is affected by the kind as well as extent of the beating, *i.e.* the wetness of the stuff, it would be possible to have a mixture of cotton fibres, the two kinds of which have equal average lengths and diameter of fibres, but by reason of the difference in their apparent specific gravities the one might sink more rapidly than the other; thus a separation would take place of two sets of fibres of equal dimensions but of different degrees of wetness. Moreover, in a tall glass jar containing a mixture of pulp as first mentioned, immediately the liquid came to rest the fibres of all dimensions would begin to settle simultaneously, so that, in spite of the larger fibres falling at a greater rate than the smaller ones, the larger fibres near the surface would reach the bottom simultaneously with the smaller ones starting near the bottom. In other words, it would be by such means, even if each sized fibre had a definite rate of settlement of its own, impossible to grade the pulp into definite-sized fibres.

But even if such grading could be effected in layers, the depth of each of which could be measured, it does not follow that, by measuring the depth of each layer in comparison with that of the depth of the total deposit, one could calculate the percentage by weight of each layer. Each layer would have a different density or compactness to the one above it.

We have assumed that there is a definite line of demarcation between each layer, whereas no such definite line of demarcation actually does exist.

Instead of attempting a separation by the settling method as above described, of course a measurement under the microscope of a number of fibres will give all the necessary data as to length and relative lengths, but as such examinations cannot be made in the ordinary course in the mill, and as these examinations give us only the *number* of fibres of different dimensions, the microscopic method has its limitations. As we wish, among other things, to determine the percentage by weight of fibres of different dimensions, some other method is desirable. We have, at various times, been confronted with the problem of ascertaining the proper sized wire for a washing drum for different kinds of stuff, and, in consequence, we have found it necessary to ascertain, in a practical manner, what proportion of fibre would pass through wire meshes of different sizes.

As a practical method of ascertaining this, we carefully dried down some of the pulp, keeping it in a very spongy condition, to insure that it would easily separate into individual fibres on shaking. Of course, in the drying of pulp from a watery solution, particularly in cases where the pulp is of a "wet" nature, there is a tendency for the fibres to felt together into a solid mass, making their dry separation a more difficult matter.

Five grams air-dry fibres taken, and shaking continued for one hour.

TABLE XLVII.

	Trial No. 1. Per cent. by weight on original.	Trial No. 2. Per cent. by weight on original.	Mean of both.
Retained on sieve of—	p. ct.	p. ct.	p. ct.
10 mesh	42·0	38·6	40·3
40 „	26·8	28·6	27·7
80 „	12·2	12·4	12·3
100 „	3·8	5·4	4·6
Passed 100 mesh	11·6	13·6	12·6
Loss by difference ...	3·6	1·4	2·5
	100·0	100·0	100·0

Average lengths of fibres—

TABLE XLVIII.

Retained on sieve of—	Mean length of fibres.	Percentage.	Length × percentage.	Relative number of mm. lengths of each dimension expressed as per cent. of total number.
40 mesh ...	3·95 mm.	× 68·0 =	268·60	83·7
80 „ ...	2·70 „	× 12·4 =	33·48	10·4
100 „ ...	1·45 „	× 5·4 =	7·83	2·5
Passed 100 mesh	0·81 „	× 13·6 =	11·02	3·4
			320·93	100·0

By determining the mean lengths of the fibres after the separation is effected, it will be noticed that they arrange themselves in order of length. It will also be noticed that it is possible to calculate the relative number of the fibres of each set of dimensions (Table XLIX.).

The above is an unbeaten short-fibre pulp, so that the fibres do not bear the same relationship in length to one another as with beaten stuff. This method of dry separation can be improved upon by having a great number of sieves of different dimensions and mechanical means of shaking to effect the separation, and by prompter precautions the loss can be reduced to less than 1 per cent. The methods of shaking in some measure effect the result, thus, if the shake is parallel to or at right angles to the plane of the sieves ; but with a little care in adjusting the conditions, the results are found to be very concordant. In the case above cited (Table XLVII.) No. 1 and No. 2 are purposely shaken in different manners, hence slight differences in the percentage separation.

The following gives the relative number of fibres of the different dimensions calculated from previous table.

TABLE XLIX.

	Per cent. by weight. ÷ Mean length in mm.	=	Relative number of fibres of each dimension.
Retained on sieve 40 mesh ...	68·0 ÷ 3·95	=	17·22
„ „ 80 „ ...	12·4 ÷ 2·70	=	4·59
„ „ 100 „ ...	5·4 ÷ 1·45	=	3·72
Passed sieve of 100 „ ...	13·6 ÷ 0·81	=	16·79
			42·32

TABLE L.

The relative number of fibres present expressed as a percentage of a total number of fibres present, calculated from foregoing table.

Retained on 40 mesh	... ...	40·6 per cent.
" 80 "	... ...	10·9 "
" 100 "	... ...	8·8 "
Passed 100 "	... ...	39·7 "
		100·0 "

For the grading of fibres into different dimensions, the mechanical method of dry sieving, where the nature of the pulp will permit it, is all that is necessary. When 10 grams dry weight are taken, the percentage is arrived at, without calculation, merely by shifting the decimal place one place to the right. The figures, as given in Table XLVII., contain all that would be necessary for mill records.

For the purposes of explosives, cotton is sometimes tested to ascertain the rate at which it wets in contact with water. This is done by allowing some of the material to fall on the surface of water, and noting how long it takes to disappear. We have tested various pulps in this manner. In the methods we employ the pulps are dried, and pressed into loose wads, occupying 15 × 10 mm., and weighing 0·1 gram. The wads are let fall through a certain depth on to the surface of a column of water, and by means of a stop-watch the exact length of time necessary for the stuff to disappear through surface is noted. A tall glass jar is used for the purpose, and the surface of the liquid kept on a level with the eye, so that the operation can be carefully observed.

The following table gives some idea of the wetness by means of this test :—

		Mean of four tests.
Cotton wool (ordinary) more than	... ...	24 hrs.
Bleached but unboiled short-fibred cotton	...	31·3 secs.
Cotton once boiled in 1 per cent. caustic soda	...	12·3 "
Cotton once boiled in 2 per cent. caustic soda	...	5·7 "
Cotton boiled and bleached and boiled again	...	4·0 "

In some cases the figure was brought down to 0·5 second, as when the cotton was extracted with alcohol and ether after chemical treatment. The test, in our opinion, is a very good one if done under uniform conditions. In all the above cases the cotton was from unbeaten stuff.

The same method may be employed to determine the comparative wetness of different samples of beaten pulp. It is rapid, efficacious, and gives a definite figure for each sample. We prefer to dry down the samples by contact with alcohol, using air-blast and as little heat as possible.

By noting the comparative wetness of the stuffs in the beater and on the machine, and taking samples of each, re-drying them, dipping equal weights into water for a given time and weighing same after they have drained, we have again a measure of the relative wetness, the wetness being in proportion to the amount of water retained.

The following method may be employed. Weighed samples are taken from the beater, each drained in a particular manner, as on a funnel-shaped piece of wire gauze of definite mesh, and after draining re-weighed, and again weighed after drying down. The amount of water retained after draining, in comparison with the dry weight of the stuff, gives the figure for the relative wetness, which we consider a satisfactory one. We have been in the habit of employing this method, where practicable, in preference to the above method of weighing dry before re-wetting, because, during the process of drying down, the hydration of the stuff is affected, and it does not therefore follow that, on re-weighing, the amount of water retained will represent the wetness of the stuff as it *originally* existed in the beater.

There are, it will therefore be noted, two kinds of wetness in pulp—one as measured by the *rate* at which pulp becomes wetted when, in a dry state, it is suddenly brought in contact with water, and the other as the power or capacity which pulps have of *retaining* water after wetting or beating.

Dr. Paul Klemm has devised an ingenious apparatus for the purpose of classifying paper pulps, whether half-stuffs or beaten pulps, according to their "wet" or "free" character, and thus estimating the amount of treatment which they have to undergo or have undergone, as the case may be, in order to fit them for the manufacture of papers of correspondingly dense or bulky characters.

Dr. Klemm, in a contribution to the WOCHENBLATT FÜR PAPIERFABRIKATION,* gave a full description and illustration. This apparatus, as shown in Fig. 30, is manufactured by L. Schopper, of Leipzig. It consists of a graduated glass cylinder held at the middle by a clamp attached to an axle, which can be rotated by a hand-wheel. Both ends of the cylinder are fitted with metal caps, which are readily removable, the top cap

* *Vide* PAPER TRADE REVIEW, January 17, 1908.

being provided with an air-cock, and the bottom one carrying the wire-sieve bottom, covered by a metal plate, which can be swung out of the way by releasing a catch.

In dealing with air-dry half-stuffs, 2 grams of the material are weighed out, dipped in water, and kneaded to a paste with a little water in a porcelain basin. As soon as the lumps are disintegrated, the pulp is washed into the cylinder, and the volume is made up to 200 c.c. with water. The top cap is then put on, the air-cock is closed, and the cylinder is whirled round by means of the hand-wheel until the fibre is evenly distributed in the water. The cylinder is then brought into the vertical position and held by a catch, the air-cock is opened, and the wire-sieve bottom is immediately exposed by dropping the covering plate. The water runs out, and the fibre is deposited on the wire in the form of a cake, the volume of which can be read off on the graduations, allowance being made for the curvature of its surface.

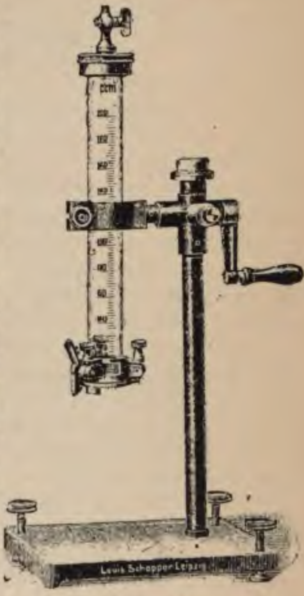


Fig. 30.

In the case of samples taken from the beater, these can be squeezed in the hand so as to contain approximately 33 per cent. of fibre, and 6 grams of the moist pulp are then taken for the experiment. In such cases the results must be subsequently corrected by drying a portion of the pulp, and ascertaining the actual weight of air-dry fibre in the cakes. The cakes may be removed without breaking them, and preserved for reference.

At the time of writing, the extreme limits observed, in the case of commercial half-stuffs, for the volume of 1 gram. of fibre, are 9 c.c. and 26 c.c. The highest values are found in the case of soda wood pulps, then follow, in decreasing order of bulk, cotton rag, sulphite wood, linen rag, and straw half-stuffs. Mechanical wood pulps show the lowest values for bulk, but these partake more of the nature of whole-stuffs. The average values for unbleached pulps are higher than those for bleached pulps.

CHAPTER XVIII.

The position of the beaters in old and new mills.

It would, perhaps, be of advantage, in conclusion, to take a glance at a fair type of ancient paper-mill, and contrast same with one of modern type, and at the same time to notice the position of the beaters in each system.

As changes are from time to time made in the processes of manufacture, so the general arrangement of a factory has to be modified to comply with these changes. The laying out of a paper works in accordance with modern requirements is a very big subject, involving many considerations, for it not only depends on the class of paper or papers to be produced, whose name is legion, but it also depends on local considerations which cannot here be entered into.

Perhaps we may with advantage show a contrast between the earliest arrangement of a paper factory of which we have authentic records, and that of an up-to-date factory of the present time.

We have searched in vain for records of the laying out of a paper works of ancient date in this country. We have not only searched literature, but also have tried to throw light on the subject with the assistance of papermakers who might possess old records, but without success. The earliest record in our possession is of German origin, and dates from 1735. In this mill we find the water-wheel communicating, by means of wooden spur-wheels, with two countershafts, the right-hand being provided with projections not unlike that which operates an ordinary musical box, disposed so that the various stampers, arranged in groups of four, rise and fall at regular intervals in the scooped-out recesses in a log of wood, of the type as illustrated in Fig. 2, p. 3. The left-hand countershaft is provided with two flanges, covered on one side with projecting wooden teeth, which engage with other teeth on a wooden disc on the end of spindles driving the rolls

of Hollanders, as shown in Fig. 3, p. 4. This mill was constructed during the transition stage between stampers and Hollanders, and therefore is provided with both. It is provided with bins in which the damped rags are allowed to ferment, and vats for the stuff, and a wooden press with a long arm for couching the sheets, and all the other impedimenta and utensils required for the manufacture of hand-made paper. The whole is enclosed in a rectangular building, the roof or top story of which is used for drying the paper. Hence the term "loft-drying."

Contrast this with a mill of the present time. We will first take a typical English mill making printings and writings. The material is elevated from the store to the highest level. From thence it undergoes the process of dusting, then of boiling, of breaking-in, and beating. From the time the material is first elevated to the time that it reaches the stuff-chest it is falling to lower levels. In other words, the force of gravity is utilized to convey the material from one department to another until it reaches the paper machine, which is in a line with the rest of the processes. The machines of each department run in rows at right angles to the direction of general travel of the stuff—*e.g.* the rag boilers, the washers or breakers, the beaters, the stuff chests, and the strainers.

The railway siding should be favourably situated both for delivering raw material and taking away the finished product. The ventilator over the top of the drying cylinders should be sufficient to rapidly take away the moist air due to the evaporation of moisture from the surface of the dryers as the paper passes over the machine. The finishing room, or salle, as it is sometimes called, is, with a one-machined mill, conveniently placed by the side of the paper machine.

For an example of a different class of mill altogether—*i.e.* that used in the production of "news" paper—we are permitted to refer to the new mill of Messrs. Peter Dixon & Sons, of Grimsby, which, at the time of writing, is the only new mill completed during the last twenty years, although it is now being followed by at least one other large mill. Here we notice that, in consequence of the raw material being already in the form of pulp before it reaches the mill, there is no necessity for dusters, cutters, fibre boilers, etc., the raw material being dumped straight away into the breakers or beaters. Here we have the Hemmer beater with independent means of circulation, together with the Hibbert beater; these together with two Marshall refiners are driven off one line of *shafting in* a direct line with the steam-engine.

The two stuff-chests for the two paper-machines are on either side of the machine-room. The paper-machines face one another—*i.e.* the one is a right-handed machine and the other a left-handed. This enables the two machines to be both operated from the central aisle of the machine-house, and the driving gear of each to be located on the two walls. The boilers are situated at one extreme of the line of buildings, and close to the main engine, whose driving-shaft is in a dead straight line with the centre of the main building. There is ample room for pulp store, which is against the beater-house, where it is required for use, and the paper-store covers the far end of the machine-house. At the end of the paper-store the railway siding is situated, at such a level that the trucks can easily be loaded up with the finished paper.

APPENDIX.

LETTERS FROM SIR JAMES M. MURRAY TO THE AUTHOR, CONCERNING THE DERIVATION OF THE WORDS "POTCHER" AND "POACHER."

Dec. 10th, 1906.

DEAR SIR,

In the preparation of the (Oxford) NEW ENGLISH DICTIONARY, we have come across the verb *poach* or *potch*, with its derivatives *poacher*, *poaching* engines used in the process of papermaking. The manager of the University paper-mill, at Wolvercote, has lent us your CHAPTERS ON PAPERMAKING, Vol. II., where, at pp. 65 and 87, I find mention of a *poacher*.

These words are quite new to us, and you would give us good help if you would kindly send us explanations of them, especially of the verb to *poach* or *potch*, and of the engine or vessel called a *poacher* or *potcher*; also if you can give us any information of the age of these words in papermaking, and give us the earliest occurrences of them that you happen to know of.

We conjecture that the word is the same *poach*, or *potch*, that is applied to the trampling and churning of moist ground into muddy holes by the feet of cattle, as one may see in any field where there is a pond or drinking-place; it is also applied to the reduction of clay into a uniform pasty consistency by a machine in the process of brickmaking. If our conjecture is right, "poaching" in papermaking ought to mean reduction of the rags or other fibrous matter to the form of pulp.

In the quotation that we have—all quite recent—the spellings *poacher* and *potcher* seem to be used indifferently; this is also the case with the poaching, or potching, of soft ground, and of clay in brickmaking, and help to make us think that the words are the same.

Yours very truly,

JAMES M. MURRAY.

Dec. 12th, 1906.

DEAR SIR,

Many thanks for your kind reply about *poacher* or *potcher*. There is no sense of *poach*, or *potch*, meaning "to warm" in English or any European language, and as the person who introduced *poach* into *papermaking* is not likely to have arbitrarily invented a new word with a new sense, we have to consider in what sense poach or potch was already in use. That of "mix up by stirring or poking with a stick or paddle" seems to come very near it. I observe that among the dialect uses of the verb *poach*, *potch*, now in use, are to stamp and turn over clothes in washing with a wooden instrument resembling a dolly, and "to do any kind of work in a liquid or semi-liquid substance in a dirty, clumsy manner." So I suspect that the use in papermaking was originally a workmen's term, which would also account for the unfinedness of the pronunciation and spelling.

Yours very truly,
J. M. MURRAY.

LETTER FROM MR. LEWIS EVANS TO THE AUTHOR ON THE SAME SUBJECT.

Jan. 18th, 1907.

DEAR MR. BEADLE,

I have been unable to find any mention of potching in any English books on papermaking, except the modern ones, nor can I find in the older French, German, or Dutch books on the subject any technical word from which it might have been derived by papermakers. The word seems, however, to have been used at least sixty years ago, in the sense of kneading or stirring, as soil is said to be poached up where horses or cattle have crowded through a gateway in wet weather on a clayey soil. An old workman, whose memory goes back sixty years, says that potching, or poaching, was applied to the preparation of rag-pulp in the "forties." I have been unable to find the word in old books or writings on papermaking.

Yours very truly,
LEWIS EVANS.

LETTER FROM MR. JOHN SMITH.

Re DERIVATION OF WORD "POTCHER."

I have seen old Shinner this morning, and after explaining the matter to him, he tells me they used to "potch" the stuff with a potching-stick in a chest during the bleaching, before there were any potchers.

So it seems that the potcher takes its name from the action of

potching the stuff, in other words, stirring it. They had breakers for breaking it in at the time; this goes back to the year 1840. He was in Bank Mill when they made the banknotes by hand, and has lots of stories to tell of that time. Paper was 2*s.* 6*d.* per lb. in those days.

JOHN SMITH.

PENICUICK,
Jan. 10th, 1907.

LETTER FROM MR. OGILVIE BRICKNALL TO THE AUTHOR CONCERNING THE SAME SUBJECT.

March 29th, 1907.

DEAR SIR,

I have worked in paper-mills for about forty years, and words and phrases are rather a study of mine, and in Scotland I never heard the word used in any other sense or meaning except that of "to stir," and that is just what a "potcher" does. In all my experience I never heard a stirring-stick called anything else than a "potching-stick." Therefore, I think *potch* is "to stir," or "mix up." What about *hotch-potch*, "all mixed up together"?—and there is a similar word (Scottish), which is *hotching*, *i.e.* simmering, or "all in a move." The word is used by Norman Macleod in the STARLING, when he describes the woods as "hotching" with birds and bird music.

LETTER FROM SIR JAMES M. MURRAY TO THE AUTHOR, IN WHICH HE GIVES A FINAL EXPLANATION.

Jan. 18th, 1907.

DEAR SIR,

Accept my best thanks for sending us the interesting results of your investigation as to *potch*, or *poach*. They quite confirm the notion I had as to the original meaning of the word, that it could have nothing to do with *heating* or *temperature*, but must be the common Scotch and dialect word *potch*, or *poach*, which means primarily to poke or thrust forcibly with the tip or end of anything, and is then applied to various actions in which this is done. Thus an illicit fisher *poaches* the overhanging "hags" of burns and rivers with a stick to disturb and net the trouts (he is the original "poacher," whence the name is extended to those who poach game preserves); a washerwoman potches the clothes with a dolly or stamper in a dolly-tub in the North; a brickmaker potches the clay to make it plastic; and horses and cows potch the soft ground round a pond into mud with their legs and feet.

The word must have come south from the Scottish paper-mills,

and being a mysterious word to the Southern, he associated it with poached eggs (*œifs poches*), and fastened upon the *heating* as the probable cause of the name, whereas it is merely incidentally connected with the actual *potching*.

I am sorry that we did not know of these in December, in time for us to use them. Fortunately, my conviction of what *potch*, or *poach*, must mean kept me from going wrong, but it would have added to the historical value of our article to tell that the term was in use in Scotland sixty years ago, and that it had evidently come south from Scotland, and in the use of those who did not know the primary sense of the word had somewhat specialized its meaning.

Yours very truly,

J. M. MURRAY.

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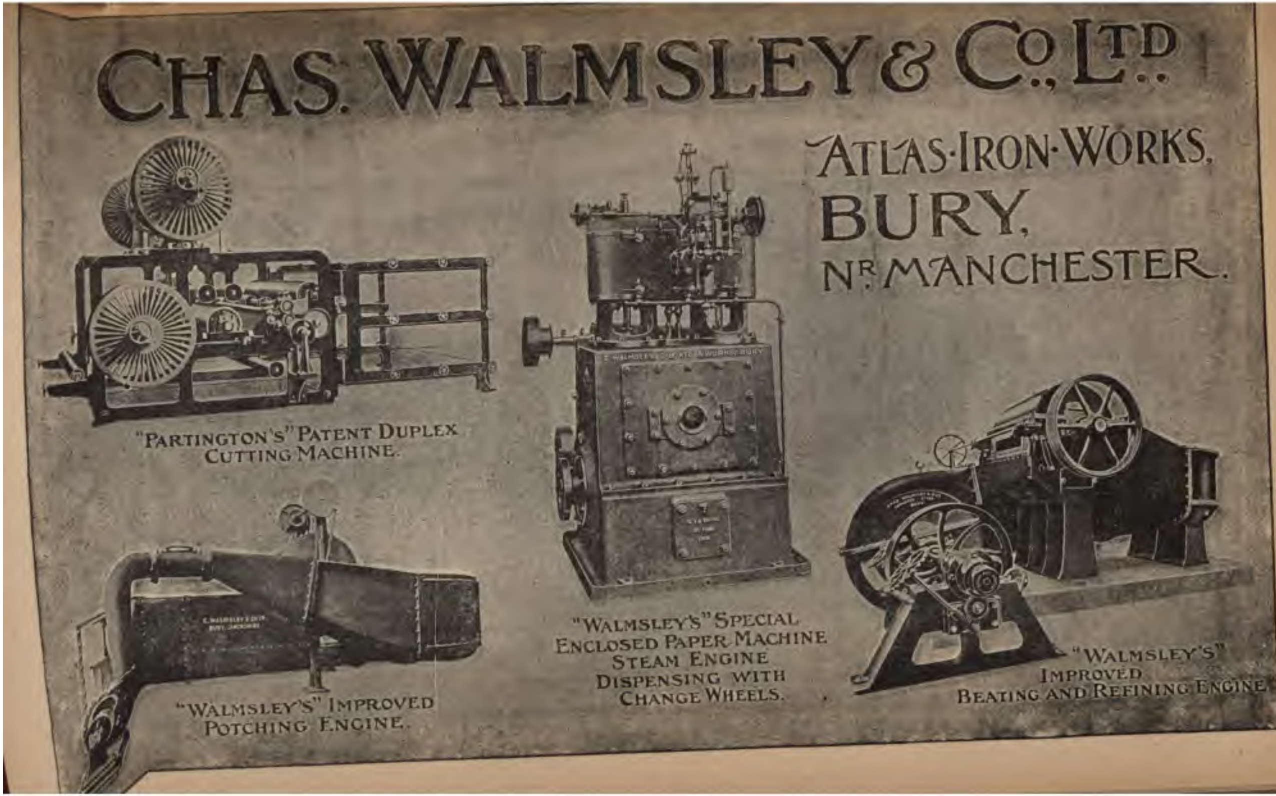

CHAS. WALMSLEY & Co., LTD.
ATLAS·IRON·WORKS,
BURY,
Nr. MANCHESTER.
"PARTINGTON'S" PATENT DUPLEX CUTTING MACHINE.
"WALMSLEY'S" SPECIAL ENCLOSED PAPER MACHINE STEAM ENGINE DISPENSING WITH CHANGE WHEELS.
"WALMSLEY'S" IMPROVED BEATING AND REFINING ENGINE.
"WALMSLEY'S" IMPROVED POTCHING ENGINE.

BERTRAMS' PATENT ROPE DRIVE.

Gives thorough control of the draws of paper throughout the papermaking machine.

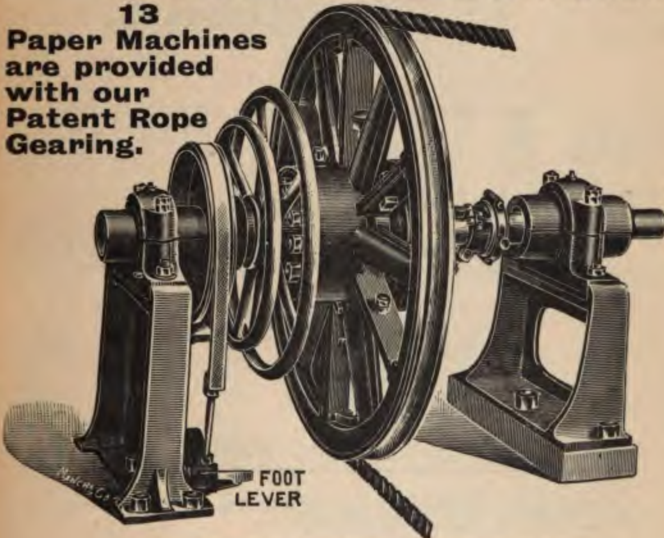
Absolutely regular and smooth running without any jerking motion.

Extreme simplicity of details, which simplicity is not lessened in the complete drive necessary for the largest machines.

Goes into the least possible space.

Only one rope needed to drive machine from couch rolls to reel.

13 Paper Machines are provided with our Patent Rope Gearing.



Shaft connected to section of Paper Machine.

PATENT EXPANDING ROPE PULLEY

FOR SECTIONAL DRIVING OF PAPER MACHINES.

Code Word: "EXPANSURE."

BERTRAMS LIMITED, ENGINEERS, SCIENNES, EDINBURGH.

Automatic stretching arrangement takes up slack of rope, and that when the rope is not under the tension of power exerted.

No cumbersome parts to lift or lower when stopping or starting any section of the machine, the stopping or starting of each section being effected without any skidding of a pulley on a belt.

No overhead shafts nor bevel gear necessary.

For a machine having say eight sectional drives, only 16 bearings are necessary on entire shafting from couch roll to reel.

BERTRAMS LIMITED

Paper Mill Machinists,

St. Katherine's **Works, SCIENNES, EDINBURGH.**

2 Plates
3 Portraits

Beadle's "Chapters on Papermaking," vol. v.

Back end papers.